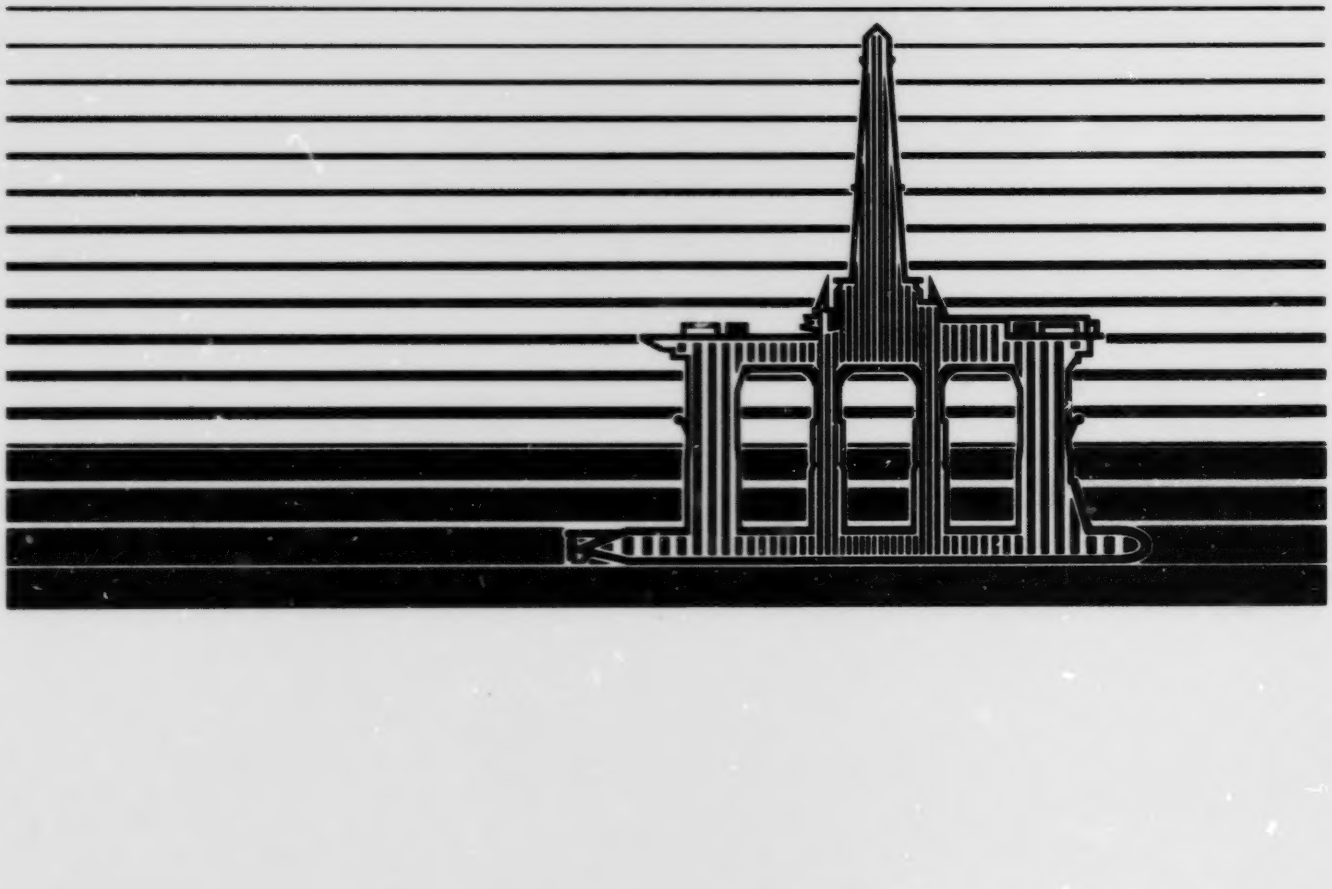
Royal Commission on the
Ocean Ranger Marine Disaster

Canada

Commission Royale sur le
Désastre Marin de l'*Ocean Ranger*

Newfoundland & Labrador



Report One: The Loss of the Semisubmersible Drill Rig *Ocean Ranger* and its Crew

85-0203/

The Royal Commission on the *Ocean Ranger*
Marine Disaster was jointly established and
funded by the Governments of
Canada and Newfoundland

Report One: The Loss of the Semisubmersible
Drill Rig *Ocean Ranger* and its Crew

Royal Commission on the
Ocean Ranger Marine Disaster
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Commission Royale sur le
Désastre Marin de l'*Ocean Ranger*
Newfoundland/Terre-Neuve

To Her Excellency
The Governor General

May It Please Your Excellency

We, the Commissioners appointed to inquire into and report upon the reasons and causes for the loss of all members of the crew of the semisubmersible self-propelled drill rig Ocean Ranger and of the Ocean Ranger on the 15th day of February, 1982 on the Continental Shelf off Newfoundland and Labrador and to inquire into, report upon and make recommendations with respect to safety offshore Eastern Canada, beg to submit to Your Excellency the following first report, which is the final report on the loss.

Chief Justice
The Honourable T.A. Hickman
Chairman

Gordon A. Winter.
The Honourable G.A. Winter, O.C.
Vice-Chairman

Fintan J. Aylward, Q.C.

Jan Furst.
Jan Furst, P.Eng.

MOMorgan
M.O. Morgan, C.C.

B. Pardy
N. Bruce Pardy, P.Eng.

August, 1984
St. John's, Newfoundland

Commissioners/Commissaires

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The Honourable Gordon A. Winter, O.C., Vice Chairman/Vice-Président
Fintan J. Aylward, Q.C.
Jan Furst, P. Eng.
M.O. Morgan, C.C.
N. Bruce Pardy, P. Eng.

Counsel/Conseiller juridique

Leonard A. Martin, Q.C.
David B. Orsborn

Commission Secretary/Secrétaire de la Commission

David M. Grenville

Fort William Building
Edifice Fort William
P.O. box/c.p. 2400 St. John's, Newfoundland/St. Jean, Terre-Neuve; A1C 6G3 · 709 · 772-4319, telex 016-4720

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Available in Canada through

Authorized Bookstore Agents
and other bookstores

or by mail from

Canadian Government Publishing Centre
Supply and Services Canada
Ottawa, Canada K1A 0S9

Catalogue No. Z1-1982/1-1E Canada: $29.75
ISBN 0-660-11682-0 Other Countries: $35.70

Price subject to change without notice

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ACKNOWLEDGEMENTS

This report is a distillation of a large volume of technical data and testimony. It has been a mammoth task to organize, analyse, reduce and present this material. The Royal Commission has been fortunate in its dedicated staff who have ably undertaken this work and who have devoted long hours to it over an extended period. We thank them individually and collectively for what they have done and continue to do.

We also wish to express our appreciation to our Chief Technical Advisor, Dr. Ewan Corlett and his assistants, who were present throughout the diving operation on the Grand Banks and involved with each phase of the model testing program and the analysis of the technical evidence. Thanks are also due to the master and crew of the diving support vessel *Balder Baffin* and to the diving team from Hydrospace Marine Services Limited without whose courage and competence neither this Royal Commission, nor the other agencies who were given access to the vital evidence recovered during the dive, could have identified the causes of this major disaster.

We also acknowledge the contribution of the scientists and technical staff at the National Research Council in Ottawa and the Norwegian Hydrodynamic Laboratories in Trondheim who undertook and brought to a successful conclusion an innovative model testing program. We have been assisted throughout this process by Dr. Derek Muggeridge of Memorial University of Newfoundland who maintained technical liaison with all the participants in that program. The Aviation Safety Engineering Division of Transport Canada undertook the technical analysis of the electrical equipment and portholes recovered from the ballast control room of the *Ocean Ranger*. This work, carried out under the direction of Mr. Max Vermij, has provided an important part of the basis for our findings. In conclusion, we express our appreciation for the wise counsel of Dr. Omond Solandt, C.C., Senior Advisor to the Royal Commission, who has helped us in all aspects of our inquiry.

For all those others who have helped us over the past two years but are not mentioned by name, we express our appreciation and warm thanks.

The Honourable T. Alexander Hickman, Chief Justice
Commission Chairman

PREFACE

Early on the morning of February 15, 1982, the semisubmersible drilling unit *Ocean Ranger* capsized and sank on the Grand Banks, 170 nautical miles east of St. John's, Newfoundland, Canada. The entire 84-man crew was lost in this disaster. Of the 69 Canadian crew members, 56 were residents of Newfoundland and the shock wave created by the loss was felt particularly throughout that province. In that tightly-knit maritime community there were few who did not discover a link, direct or indirect, to one of those lost in the tragedy. The inquiry by this Royal Commission is therefore of unusually deep concern to Newfoundlanders. It also has important implications for the rest of Canada and for other maritime nations engaged in the search for offshore oil and gas.

It is normal practice under the *Canada Shipping Act* for the Marine Casualty Investigation Branch of Transport Canada to conduct a preliminary investigation into any loss that falls within the meaning of a shipping casualty under the *Act*. Thereafter, if a formal investigation is to be held, a Court consisting of one or more Judges is appointed under the provisions of the *Canada Shipping Act* to investigate the loss. The *Act* provides that the Court be assisted by two or more assessors. This procedure was followed in the case of the *Ocean Ranger* but, because of the breadth of the inquiry, Chief Justice the Honourable T. Alexander Hickman of the Supreme Court of Newfoundland, Trial Division, was appointed not only a Commissioner under the *Canada Shipping Act* but also a Royal Commission of one under Part One of the *Inquiries Act*. The Government of Newfoundland also appointed a Royal Commission to investigate the loss. Subsequent public concern was expressed that the existence of two official investigations would create problems and a duplication of effort. Both levels of government responded swiftly by agreeing to combine the inquiries and adopt identical terms of reference through the joint appointment of a Royal Commission under the Chairmanship of Chief Justice Hickman. The Chairman of the Provincial Royal Commission, the Honourable Gordon A. Winter, O.C., was appointed Vice-Chairman.

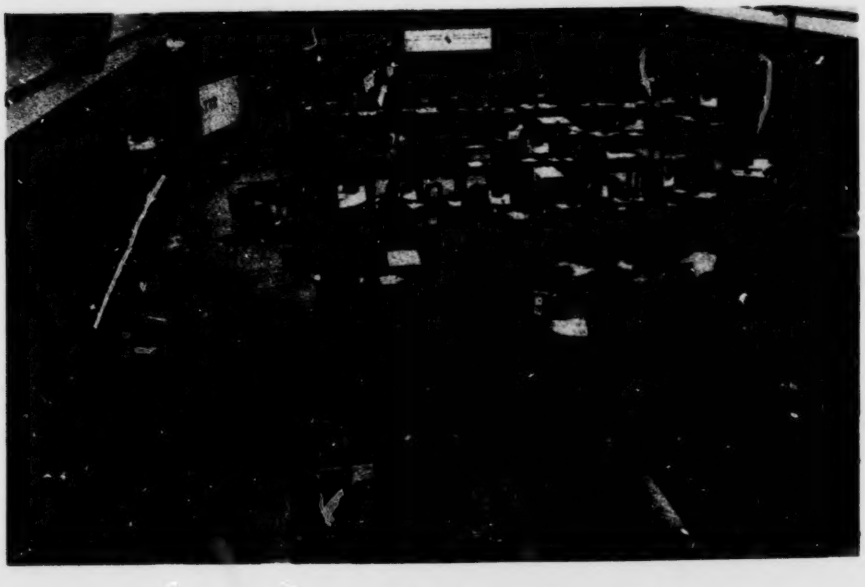
In jointly establishing this Royal Commission, the two governments gave it a unique and challenging mandate divided into two parts: the first requiring a formal (quasi-judicial) inquiry into the loss of the *Ocean Ranger* and its crew; the second calling for a process of research and opinion-gathering directed towards providing recommendations to both governments on how to improve the safety of drilling operations on the continental shelf off Eastern Canada.

What makes the *Ocean Ranger* inquiry different is the breadth of Part One of the mandate which directs the Royal Commission to examine not only the cause of the loss, but also areas of vulnerability within which lay the potential for this disaster and the seeds for future ones. This latter aspect is the basis for the transition from the specific concerns of Part One to the more general inquiry called for in Part Two. In considering this mandate, the Commissioners decided that their major task was to address future safety offshore and that the investigation of the loss of the *Ocean Ranger* and its crew should go beyond the realm of acceptable conjecture or reasonable deduction based upon circumstantial evidence. It should endeavour through scientific investigation to determine why in fact the *Ocean Ranger*, alone of the three rigs on Hibernia, capsized and sank during a severe winter storm.

One of the first actions of the Royal Commission was to issue a formal order forbidding any approach to or disturbance of the wreck of the *Ocean Ranger*. Shortly thereafter, it awarded a contract for an underwater examination of the rig to obtain technical data and to find, and, if possible, to recover evidence which would explain the cause of the loss. The portholes, ballast control panel, and related electrical equipment recovered during the dive were subjected to extensive analysis and testing. A number of major technical investigations were also initiated, the most far-reaching of which was a comprehensive program of model tests. These tests were carried out jointly by the National Research Council of Canada in Ottawa and the Norwegian Hydrodynamic Laboratories in Trondheim. The extensive use of model testing as an investigative tool to examine the behaviour of a mobile offshore drilling unit was unprecedented. All the reports on the technical investigations undertaken have been formally introduced as evidence at the public hearings.

While the technical program progressed, the organization and planning of the Part One public hearings proceeded in parallel. Practice and Procedure Rules for the Inquiry were drawn up and published. A Notice was published in July, 1982, in Canada and the United States, inviting Applications for Standing. Nine interested parties were subsequently granted standing with the right to be represented and to cross-examine witnesses at the public hearings, and three organizations were given official observer status. The hearings commenced on October 25, 1982. The number of sitting days totalled 89 with the hearings extending over 17 months and finishing on March 22, 1984. During this time, 102 witnesses appeared and 321 exhibits were entered in evidence resulting in 14,281 pages of verbatim transcript (Appendix A).

It was apparent from the outset that a great deal of complex information, much of it highly technical, would be processed at the hearings. An audio and video



system was installed to avoid the delays which could have resulted if all participants had not been able to hear and see the evidence as it was presented. A computerized index of the entire transcript of the evidence given at the hearings was maintained in order to facilitate searches for specific references, as well as to provide confirmation that all references to any given aspect of the evidence had been identified. This data base also contains references to regulations, reports, periodical articles and a variety of other relevant material.

The *Ocean Ranger* was registered in the United States and, as required under U.S. law, a Marine Board of Investigation was established to investigate the loss. The United States Coast Guard and the National Transportation Safety Board, an independent United States Federal Agency, participated jointly in this investigation. The Commissioners realized that the process of scientific inquiry involved under their mandate would not lend itself to the production of an early interim report with credible findings. For this reason they decided that they should not be concerned whether other agencies issued their reports first, but that they would rather cooperate fully with them and share whatever information they acquired. Accordingly, the Royal Commission placed at the disposal of these agencies the results of its diving and technical investigations. Both the National Transportation Safety Board and the United States Coast Guard have since published reports of their findings which were accepted as evidence by the Royal Commission. In like manner, information needed by the Governments of Canada and Newfoundland in their inquiries and in their formulation of new guidelines, regulations or policies was provided as it became available. This policy was adopted to ensure that the process of investigation did not inhibit the necessary process of improving safety offshore.

Canadians from all parts of the country are now employed in exploratory drilling operations off Eastern Canada. Responsibility for their safety and for the proper conduct of this major new industry in Canadian coastal waters has been assumed by government both nationally and provincially. The international maritime and oil industries have a keen interest in how these responsibilities are administered. Much has been achieved by governments and the industry over the past two years. But a great deal still remains to be done.

INTRODUCTION

The primary purpose of this report is to set forth the results of the inquiry of the Royal Commission into the loss of the *Ocean Ranger* and its crew. This inquiry has addressed three basic questions:

Why did the *Ocean Ranger* capsize and sink?

Why was none of the crew saved?

How can other similar disasters be avoided?

This report will provide an answer to the first two questions and an initial response to the third. A broad investigation has been launched into this third area to identify practical means of improving human safety during drilling operations off the east coast of Canada. The results will be presented in a second and final report.

When it was launched in 1976, the *Ocean Ranger* was the largest, self-propelled semisubmersible offshore drilling unit in the world. Designed by ODECO Engineers Incorporated for ODECO International of New Orleans, Louisiana, and the Norwegian firm of Fearnley & Eger A/S, it was built at the Hiroshima yard of Mitsubishi Heavy Industries. The rig's maiden voyage in June of that year led from Japan to Alaska. After completing wells in the Bering Sea, the Gulf of Alaska and the Lower Cook Inlet, it left the area in September 1977 and remained idle, moored at various locations on the west coast of North America until August 1979. The rig was then moved east via Cape Horn to drill a well in the Baltimore Canyon off New Jersey, thence to Ireland in May 1980 for another two wells, and finally back across the Atlantic to arrive on the Grand Banks of Newfoundland on November 6, 1980 (Appendix D, Item 1). The *Ocean Ranger* began drilling in the Hibernia Field on contract between Mobil Oil Canada Limited (Mobil), the operator for the Hibernia Consortium, and ODECO Drilling of Canada Limited (ODECO). This contract, signed in February 1980, was initially for 13 months, but after its expiry a two-year agreement was negotiated and accepted by both parties. Under this contract, ODECO was responsible for the rig and the crew and Mobil was responsible for the well.

The *Ocean Ranger* was built and classed in accordance with the 1973 rules of the American Bureau of Shipping. The rig was originally registered in Panama, but in 1980 ODECO, then the sole owner, transferred it to United States registry. When it began to drill off the east coast of Canada, it was subject to United States regulations and, consequently, to the regulations of the International Maritime Organization to which the United States subscribed. The drilling operation itself was governed by the conditions of the permits issued to Mobil by the Government of Canada and the Government of Newfoundland and by the offshore drilling regulations of each government.

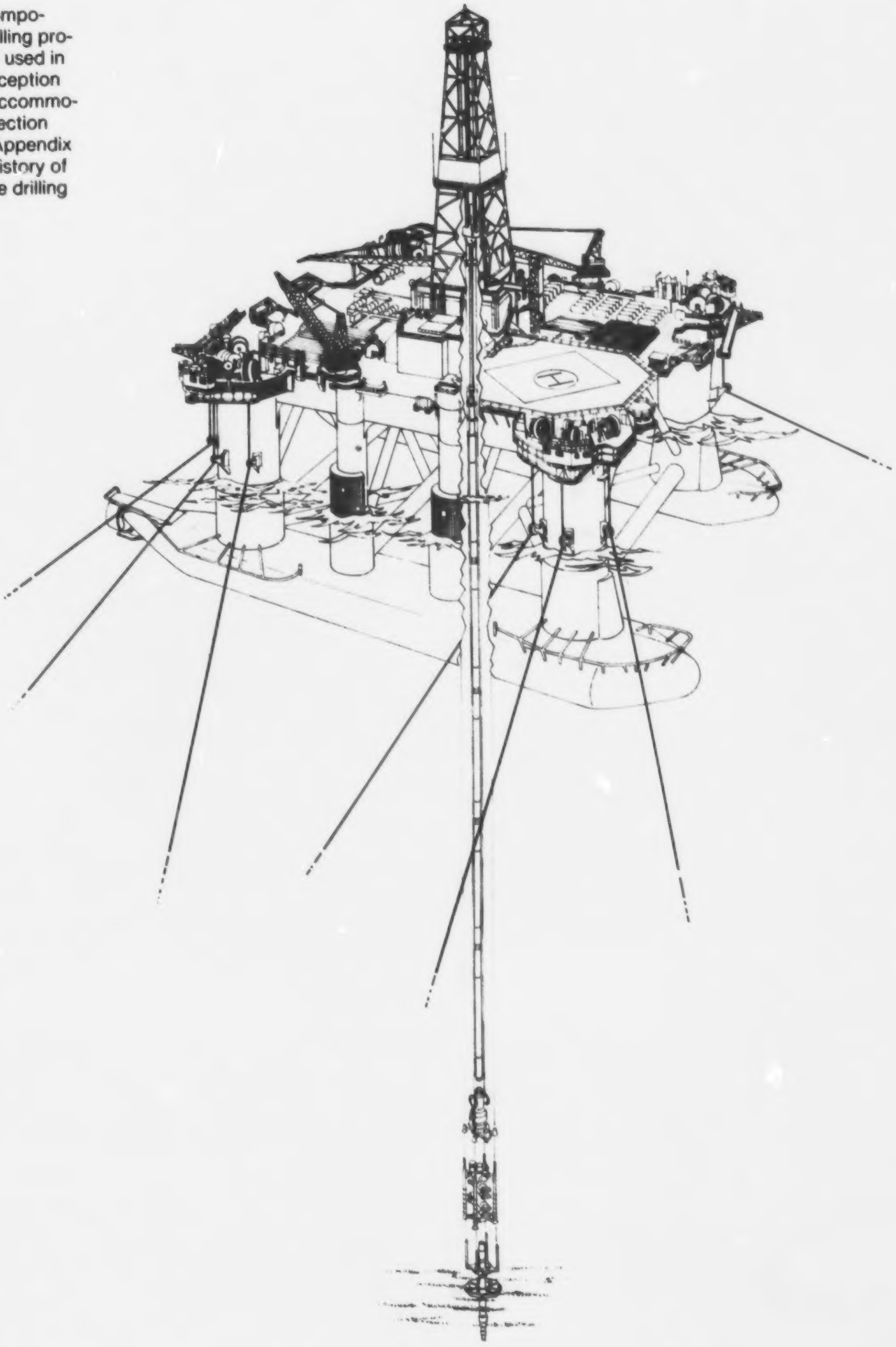
Despite its size, its reputation for invulnerability, and the regulatory control exerted over its design, construction, and operation, the *Ocean Ranger* and its entire crew were lost less than two years after the rig arrived on the Grand Banks. The enormity of this disaster was widely felt, following as it did the loss of 123 lives a year earlier when the *Alexander Kielland* capsized in the North Sea. In 1983 the *Glomar Java Sea* and all 81 of its crew were lost in a storm in the China Sea. These tragedies have focused concern on and raised questions about the reliability of the technology involved in offshore drilling operations under adverse environmental conditions and the adequacy of the regulatory agencies whose function is, at least in part, to ensure that these operations are carried out safely. The reliability of that technology and the adequacy of the regulatory structures need to be viewed in the context of the historical evolution of offshore oil exploration.

The complex technology that is currently in use by the petroleum industry to find and develop hydrocarbon resources has evolved over the past one hundred years. By the 1930's, drilling equipment and techniques used for exploration and production on land were successfully adapted to sites covered by water. Initially these were in swampland and in shallow sheltered waters inland or inshore. Pile-supported drilling platforms were succeeded by barge-supported platforms which could be floated to the site, flooded and thereby fixed in place. A further step in the evolution of offshore technology led to the development of the jack-up rig. This type of rig, the most widely used in offshore exploration today, rests on legs on the seabed and is jacked up until the drilling platform is raised above the level of the waves. Exploration rigs supported on the sea bottom are presently limited to depths of about 350 feet and cannot be used where, for instance, they may have to be moved quickly to avoid icebergs and heavy pack ice. Two developments overcame these limitations; one was the drillship, originally a conventionally designed vessel adapted for drilling, and the other was the semisubmersible, a free-floating platform supported by pontoons and columns.

This gradual evolution of offshore technology has accelerated rapidly during the last two decades. The growth in demand for petroleum, the drive to achieve national self-sufficiency in energy, the depletion of known land-based reserves and the vagaries of OPEC policies have led to a surge of exploration, on a worldwide scale, into deeper water offshore under increasingly harsh environmental conditions. The exploration sector of the oil industry has a strong tradition of tackling difficult engineering problems and solving them successfully. It has accordingly brought this approach and the practical experience on which it was based, to the evolution of offshore drilling techniques. The objective has remained unchanged: to provide a stable platform from which to drill. It is not surprising, therefore, that the pursuit of this central purpose has been by the extrapolation of existing land-based oilfield technology and the extension of tested methods.

Despite this predominantly industrial focus the activity takes place at sea. The unique nature of this industrial-marine endeavour, together with the constant evolution of new technology, has presented a challenge to agencies established to set standards and govern the design and activities of more traditional craft. These agencies have tended to evolve their standards and their role, as did the rig designers, on the basis of experience. Despite the newness and the diversity of the industry, one trend has become clear for both the participants and the regulators: offshore drilling has emerged as an industrial activity that takes place in a marine environment rather than as a marine activity undertaken for industrial purposes. Unless the coastal state decides otherwise senior industrial personnel on rigs of United States registry are in charge of the rig regardless of their knowledge of ships or the sea. The key element in the operation is the drilling. The mariners' contribution to this activity is to get the platform to the well site and to maintain it in position as stable as possible so that

This illustration shows the major components of the *Ocean Ranger*. The drilling process is essentially the same as that used in land-based operations, with the exception of the systems which are used to accommodate the rig's motion and the connection between the rig and the seabed. (Appendix B gives a brief explanation of the history of and techniques used in the offshore drilling industry.)



drilling may proceed safely and efficiently. When the rig is in transit, an experienced marine crew must be in charge and the industrial crew may not even be on board. While the rig is moored and drilling operations are underway, the marine crew, to the extent that one exists, has little to do.

It is against this dual industrial-marine focus and in light of the emerging regulatory system and evolving technology that the loss of the *Ocean Ranger* needs to be examined. In addition to inquiring into and reporting upon the reasons and causes for the loss of the rig and its crew, the Royal Commission is also required to report on a number of specific matters that are relevant to the accident. These include: the regulatory framework and how it functioned; certain aspects of the design of the *Ocean Ranger* and of its critical systems; the composition of the crew and how the rig was manned; the command structure; and operations on the Grand Banks leading up to the disaster. The first four chapters of the report cover these areas and provide background information, analyses and comments. Most of the discussion centres on those factors deemed most instrumental in contributing, although often indirectly, to the loss of the *Ocean Ranger* and its crew.

Only after this framework of secondary considerations has been established does the report deal with the accident itself and its immediate causes and results. In the fifth chapter the sequence of events leading up to the abandonment of the *Ocean Ranger* by its crew is reconstructed. This is followed in the sixth and seventh chapters by a presentation of the key technical evidence, and an analysis of the most probable cause of the loss of the rig. A reconstruction of the sequence of events following the decision by the crew to abandon the rig, the response to the emergency and its final outcome are described and analyzed in the eighth and ninth chapters. The final chapter contains the conclusions and recommendations.

Appendices, contained at the back of this report, will be referred to frequently and will be of assistance to readers who require supplementary information. Since this report incorporates numerous marine, oil industry, aviation, and other technical terms, an extensive glossary has also been included for reference. Certain words used in a particular context are footnoted and explained where they occur within the body of the report. The units of measurement reflect those recorded in the testimony and in common use within the marine, industrial and aviation sectors in 1982. Where necessary, metric units have been appended. To avoid confusion, no attempt has been made to convert to metric those units recorded in the testimony, or the units in which the *Ocean Ranger* was originally designed.

1

REGULATORY STRUCTURE

CHAPTER ONE REGULATORY STRUCTURE

From the time that it was initially designed to the time that it capsized and sank on the Hibernia Field off Eastern Canada, the *Ocean Ranger* was governed by the rules and regulations of numerous national and international bodies. Its design, construction and operation were the subject of complex sets of compulsory laws and voluntary rules established by the rig's classification society, its Flag State or country of registry, the Coastal State or country of operation and international conventions.

In reviewing the roles played by these regulatory bodies an attempt has been made to identify the scope of responsibility of each agency, to determine whether prescribed procedures were carried out by these agencies, and finally to evaluate the adequacy and appropriateness of these procedures in the case of the *Ocean Ranger*. Specific regulatory deficiencies such as those related to training, manning and life-saving equipment will be treated in the relevant chapters of the report.

CLASSIFICATION SOCIETIES

The classification of vessels originated in England over 200 years ago in Lloyd's Coffee House, where the most influential members of the shipping trade in London would gather to discuss business. Underwriters who were called upon to accept maritime risks and shippers of valuable cargo sought some guarantee of fitness of the vessel for the voyage in prospect. There evolved a rough system of inspecting hulls and equipment and a Ships' List to provide a description of the ships likely to be offered for insurance. In 1760 a committee was established and in 1765 the first Register of Shipping was produced. This committee set the standards for the construction and maintenance of ships and equipment and, on the basis of experience, developed rules which applied recognized standards. From this voluntary association evolved Lloyd's Register of Shipping which is now an international, non-profit body engaged primarily in the classification of ships and the maintenance of technical standards of shipbuilding. Its activities are controlled by a general committee consisting of shipowners, underwriters, shipbuilders, engine builders and steel makers drawn from many countries. Similar organizations have developed in other maritime nations; the Bureau Veritas in France, Det norske Veritas in Norway and the American Bureau of Shipping (ABS) in the United States.

The standards set by the different classification societies are similar and represent the cumulative experience acquired through extensive research and development work by the societies and other groups and through surveys of thousands of ships over many years. In general the societies are intended to certify that:

1. the vessel complies with a standard of construction which assures adequate structural strength under the conditions for which it was designed;

2. the vessel's electrical and mechanical systems comply with acceptable standards and are installed properly;
3. the vessel is maintained by its owner to the extent that it does not lose its classification;
4. all major repairs or structural changes to the vessel are carried out in accordance with the rules of the society.

The rules of the classification society do not apply to the seaworthiness[1] of the vessel nor to the lifesaving and navigational equipment since these are governed by international conventions and the regulations of the vessel's Flag State.

Classification societies became involved in the offshore drilling industry in the 1930s and 1940s when they applied their rules for building and classing steel vessels to barges, drilling tenders, and support vessels. In the early years of the industry, when drilling units had many of the features of conventional vessels and operated close to shore, this approach was satisfactory. But by the 1950s new designs were being created for drilling rigs which allowed them to operate farther from shore and in increasingly severe environmental conditions. As these designs evolved, they diverged increasingly from the conventional shape of ships, and it became apparent that specific rules would have to be developed for the mobile offshore drilling unit (MODU).

ABS published the first set of MODU rules in 1968 and revised them in 1973 and again in 1980. In the 1970s, Lloyd's Register, Det norske Veritas, and Bureau Veritas also developed standards for MODUs. In instances where the MODU rules did not address a particular aspect of a rig's design, the rules for ships were applied. The *Ocean Ranger* was constructed and classed in accordance with ABS's *1973 Rules for Building and Classing MODUs* and retained its classification to the time of its loss. In August 1973 ODECO Engineers Inc. requested ABS to review the *Ocean Ranger's* pre-construction plans. Later Mitsubishi Heavy Industries, the Japanese shipyard that had been commissioned to build the rig, produced more detailed plans which were approved by ABS and one of their surveyors was assigned to the work site to monitor the rig's construction. Since the rig was to operate under the Panamanian Flag, ABS was further commissioned by the Government of Panama to ensure that the rig complied with the *Safety of Life at Sea (SOLAS) Convention* and the *International Load Line Convention*. After successfully completing its sea trials and receiving ABS approval of its *Booklet of Operating Conditions* (operating manual), the *Ocean Ranger* was granted an interim classification for Unrestricted Ocean Operations Worldwide on May 28, 1976.

Section 1.17 Responsibility . . . "It is understood and agreed by all those who avail themselves in any way of the services of the Bureau that neither the Bureau nor any of its Committees and employees will, under any circumstances whatever, be responsible or liable in any aspect for any act or omission whether negligent or otherwise. . . ."

1973 Rules for Classing and Building Offshore Mobile Drilling Units
American Bureau of Shipping

There appears to have been a misconception about the role of ABS and the meaning of its classification of the *Ocean Ranger*. Classification of a drilling unit by a society simply means that the unit has been constructed in accordance with the rules of that society. It does not guarantee seaworthiness. It implies that the society, on the basis of its cumulative experience, believes that a unit so constructed will be structurally sound and sufficiently equipped for the sea conditions for which it has been classed. As a spokesman for ABS pointed out at the hearings, if others choose to give a wider meaning to classification, they do so at their peril for the limited role of the classification society is quite clearly set out in its rules.

At the time that the *Ocean Ranger* was constructed, the applicable ABS rules required that as a condition of classification each drilling unit was to have prepared to the satisfaction of the Bureau an operating manual to provide suitable guidance

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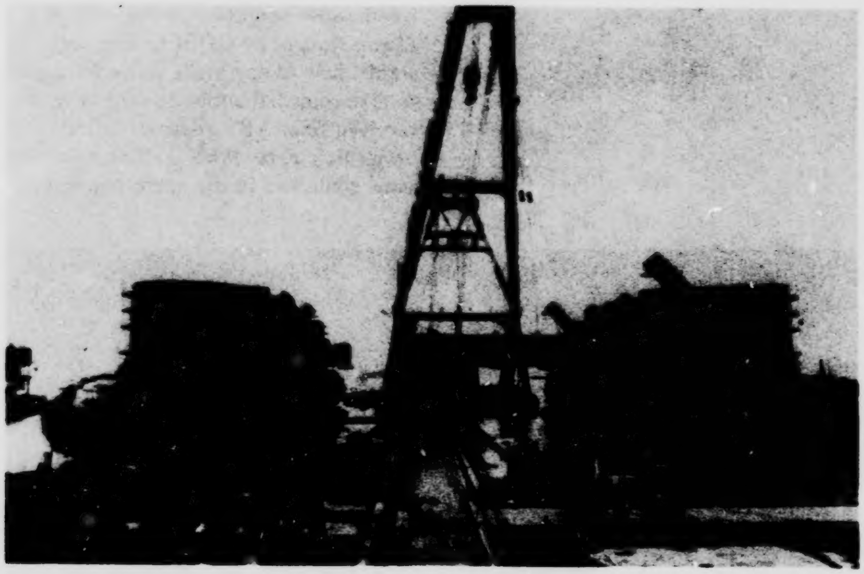
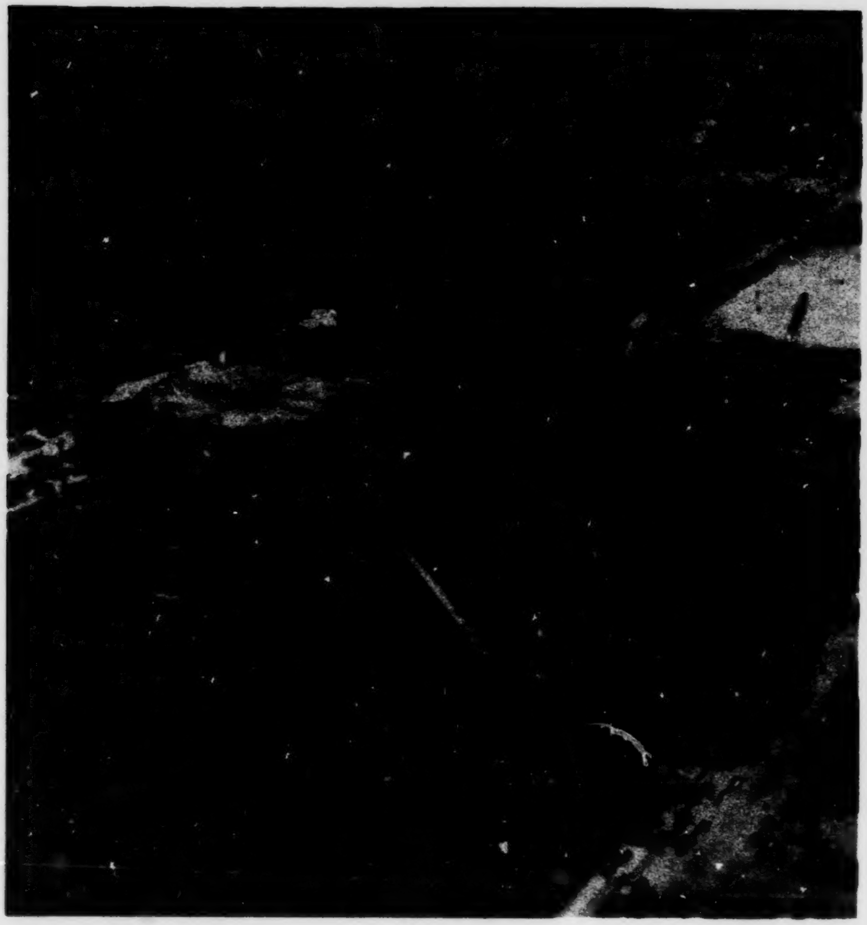
[1] According to counsel for ABS, the Bureau avoided the word "seaworthy" because of its connotation in U.S. law. "In U.S. law a vessel is seaworthy if it is reasonably adequate for the service in which it is engaged" (Public Hearings, Volume 86, p. 14,060).

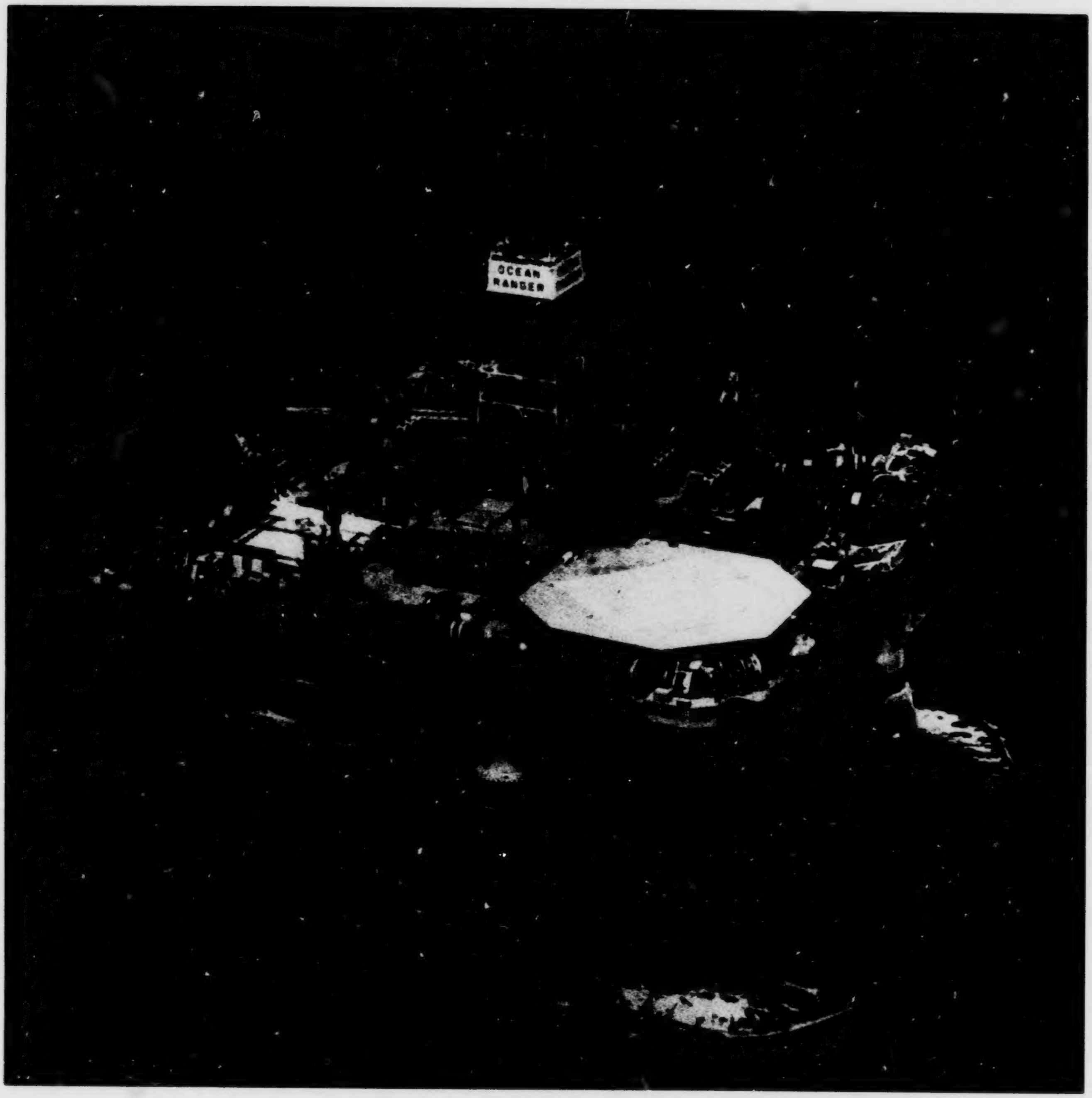


1.1 The *Ocean Ranger's* pontoons under construction at the No. 2 Eba shipyard of Mitsubishi Heavy Industries, Hiroshima, Japan. The floating crane in the background is lifting the first section of the four transverse braces into place.



1.2 With the upper hull in place, the major structural components of the *Ocean Ranger* have been completed. One of the rig's three cranes has already been installed to aid in the movement of materials during construction. The helideck above the accommodations area at the starboard bow is almost finished. The anchor bolsters, designed to protect the pontoons during mooring operations and to store the twelve main anchors, are visible near the waterline at the corner columns.

for the safe operation of the unit. A manual for that purpose was prepared for the *Ocean Ranger* by ODECO Engineers Inc. It described how to keep the rig level and stable, how to operate it safely during transit, mooring, drilling and storms, and how to take remedial action in case of severe damage. On January 21, 1977, this manual received final ABS approval as indicated by the official seal of the Bureau stamped on its first page. ABS disclaims any responsibility for the adequacy of the instructions contained in the operating manual, but its official stamp could lead third par-



ties to conclude that this approval applied to the manual as a whole and that the instructions for the safe operation of the unit contained therein were deemed by ABS to be complete and adequate. This may explain why the Flag and Coastal States did not carry out a stringent critical review of the *Ocean Ranger*'s operating procedures. The manual, however, was deficient in several respects. Of particular concern was the lack of direction for the prevention of downflooding into the chain lockers, for the closure of deadlights in the ballast control room during storm conditions, and for the manual control of the ballast system in the event of serious damage to the ballast control console. There was also no information concerning the limitations of the ballast system.

This same observation applies to the design of the rig and the interrelationship of some of its systems. One might assume, since the rig had been classed by ABS, that its ballast system could correct adverse trims or lists in a timely and proper manner. In fact this was not the case. The rules of ABS did not deal with such matters as the angle of inclination from which the rig could recover by pumping out ballast water. Nor did its rules deal with the adequacy or appropriateness of the rig's mooring system other than to test it in accordance with the specifications of the owner. Furthermore ABS had no standards relating to the thickness of portlights or to the protection of chain lockers from flooding. These are but examples of areas affecting the safety of the rig not covered by ABS rules. They illustrate that in classing a drilling unit the society certifies only that the unit has been constructed in accordance with its rules. Matters related to the safe design and operation of the rig which are not covered by these rules are the concern of other regulatory authorities which can establish and enforce their own standards.

INTERNATIONAL CONVENTIONS

The international maritime community has developed minimum safety requirements for all vessels operating in international waters. The International Maritime Organization[2] (IMO), whose membership includes most of the world's maritime nations, is the body responsible for formulating standards on marine safety, pollution, and navigation. IMO members adopt these as minimum requirements and supplement them with their own regulations. Canada, for example, supplements the IMO requirements with the *Canada Shipping Act*[3].IMO did not have standards governing MODUs when the *Ocean Ranger* was built (the first MODU code was adopted in 1980) and the two Conventions which did apply, the *Safety of Life at Sea (SOLAS)* (1960) and the *Load Line Convention* (1966) were designed for conventional vessel categories.

The *SOLAS Convention* deals with the design of a vessel as it affects the safety of life. It covers structure and machinery, communication equipment, and lifesaving appliances. The *Load Line Convention* is concerned with a vessel's freeboard under normal operating conditions and stipulates the maximum depth to which it can be loaded. The Flag State is responsible for issuing certificates verifying that a vessel meets IMO standards. These certificates are normally valid for two years. The *Ocean Ranger* was inspected for compliance with these Conventions on two occasions. In 1976 ABS inspected the rig on behalf of Panama, the *Ocean Ranger's* Flag State at the time, and in 1979, when the rig was changed to United States registry, it was inspected by the U.S. Coast Guard. At the time of its loss the *Cargo Ship Safety Equipment Certificate*, which was one of the certificates issued by the U.S. Coast Guard under the *SOLAS Convention* (1960), had expired. The rig did, however, have a valid Certificate under the *Load Line Convention* (1966).

1.3 The *Ocean Ranger* under tow in Hiroshima Bay prior to its maiden voyage from Japan to Alaska. The rig was designed to withstand 115-mile per hour winds and 110-foot seas, and at this time was the largest semisubmersible drilling unit in the world.

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[2] The Inter-Governmental Maritime Consultative Organization was formed in 1958 as a specialized agency for the United Nations; it changed its name to the International Maritime Organization (IMO) in 1982.

[3] The *Act* at the time of the loss regulated vessels registered in Canada and vessels operating within twelve miles of the shore; it therefore did not apply to the *Ocean Ranger*.

FLAG STATE

Under its new country of registry, the *Ocean Ranger* became subject to the regulations of the U.S. Coast Guard contained in the MODU section of the *Code of Federal Regulations*. First issued in January 1979, the U.S. Coast Guard regulations covered the structure, stability, operation and safety of the rig, with specific references to manning requirements and command. The inspection by the U.S. Coast Guard took place in December of 1979, and was conducted by personnel from the Marine Inspection Office in Rhode Island. The *Ocean Ranger* was the first semisubmersible inspected by that office. There is no evidence to indicate that the technical aspects of the rig's design and the capability of its ballast pumping system were assessed. It appears that the ABS classification was accepted as proof of the design's adequacy. No major deficiencies were discovered, but ODECO was directed to replace the lifeboats and life rafts with approved equipment within two years. Following approval of the *Booklet of Operating Conditions*, a *Certificate of Inspection* detailing crew requirements was granted for a period of two years.

The U.S. Coast Guard did not carry out any regular inspections subsequent to the initial one to confirm that the vessel was being operated properly and that its regulations were being followed, although one official visited briefly and prepared a list of suggested items for maintenance and changes. It is United States policy that the owner is responsible for contacting a U.S. Coast Guard office before the expiry of the certificate in order to arrange for reinspection. Up to the time of the loss ODECO had failed to contact the U.S. Coast Guard, even though the initial certificate had expired in December 1981. The lifeboats and life rafts on the *Ocean Ranger* did not meet U.S. Coast Guard requirements. It has also been determined that the rig was not manned according to requirements of the *Certificate of Inspection*, and that its *Cargo Ship Safety Equipment Certificate*, issued under the *SOLAS Convention*, had expired. The U.S. Coast Guard relied on ABS's classification for the adequacy of the design of the rig. It did not adopt inspection procedures to ensure compliance with its *Certificate of Inspection* and its requirements for lifesaving equipment. (Appendix C contains certificates and other related information.)

COASTAL STATE

When the *Ocean Ranger* was engaged to drill on the Grand Banks, it came under the additional regulatory control of two governments, the Government of Canada and the Government of Newfoundland. Because of an unresolved jurisdictional dispute over the ownership of offshore resources, each government enforced its own requirements on Grand Banks drilling operations. The Canadian Government, through the Resource Management Branch of the Department of Energy, Mines and Resources (subsequently renamed the Canada Oil and Gas Lands Administration [COGLA]), required that offshore operators adhere to the *Canada Oil and Gas Drilling Regulations (1980)*. At the same time, the operators were required to follow *Newfoundland and Labrador Petroleum Regulations (1977)* which were primarily administered by the Newfoundland and Labrador Petroleum Directorate (The Petroleum Directorate). Although the two sets of regulations differed in content, both were designed to ensure that drilling was carried out with an adequate degree of human and environmental safety. COGLA used an application-permit system to regulate all aspects of offshore drilling. They required an operator to submit for approval information on the proposed drilling program including details on the drilling unit, support craft and emergency procedures (contingency plans). In March 1980, Mobil Oil Canada Ltd., the operator for the consortium on the Hibernia Field, notified COGLA of their intention to use the *Ocean Ranger*. COGLA inspected the rig, and, although the radar system and the ventilation system were noted as being unacceptable, no major structural or safety deficiencies were found. On November 3, 1980, COGLA approved Mobil's application to drill a well using the *Ocean Ranger*. From that time until its loss, COGLA inspectors visited the *Ocean Ranger* on 19 occasions, directing their attention primarily to the safety of the drilling operation. Although the inspectors sometimes examined the lifesaving appliances, no attempt was made to determine their suitability for evacuation.

The Petroleum Directorate played a lesser role in regulating the Grand Banks operations. Although the Petroleum Directorate used an application and permit process similar to COGLA's, it relied upon others to ensure that the rig was structurally sound, seaworthy and properly fitted with lifesaving equipment. When the *Ocean Ranger* arrived on the Grand Banks, the Petroleum Directorate employed one inspector who assessed daily drilling reports for compliance with the Province's regulations. In the event of a serious breach of the operator's drilling permit, the inspector would visit the rig to conduct an on-site inspection. Although none were carried out on the *Ocean Ranger*, a number of informal visits were made by representatives from several provincial agencies including the Petroleum Directorate. The Province of Newfoundland also enforced regulations covering local preference for the purchase of goods and services associated with the drilling program, and maintained requirements for the employment of local labour on the rig.

The requirements of the classification society and the Flag State do not reduce the Coastal State's responsibility to ensure that foreign flag MODUs operating within its jurisdiction are seaworthy and that adequate marine standards and practices are applied and maintained. Representatives of both COGLA and the Petroleum Directorate admitted in evidence that they did not treat the safety of the rig's marine operations as a priority. Since the sinking of the *Ocean Ranger*, the U.S. Coast Guard, COGLA and the Petroleum Directorate have all increased the rigour of both regulations and enforcement policies.

1.4 The *Ocean Ranger*, on the Hibernia J-34 well off Eastern Canada during December 1981, is shown at the 80-foot drilling draft. Some of the twelve anchor cables are visible running from the fairleads on the corner columns.

2

THE *OCEAN RANGER*

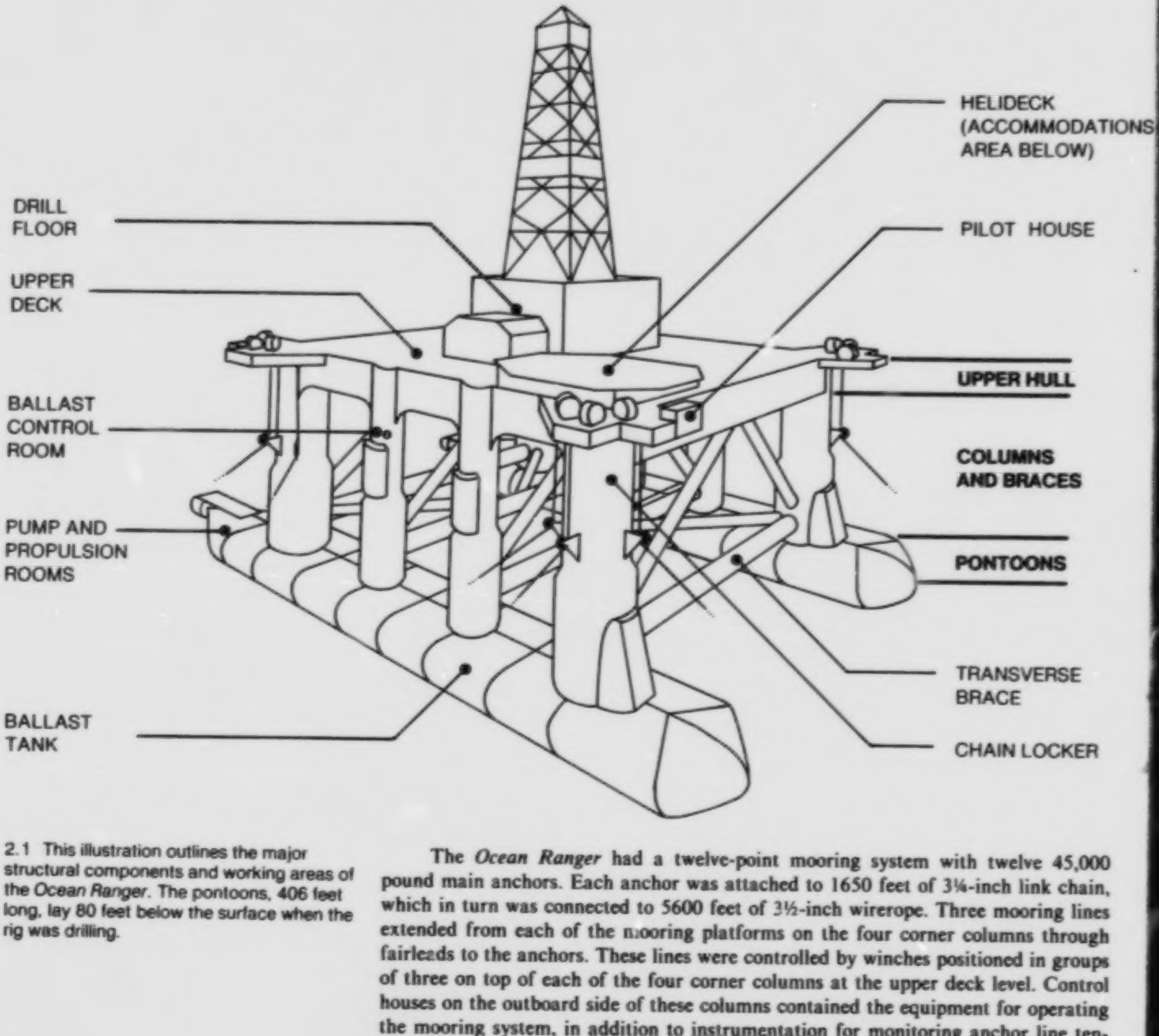
CHAPTER TWO THE OCEAN RANGER

This chapter contains a description of and observations regarding the structure and layout, the ballast and communications systems, and the lifesaving equipment of the *Ocean Ranger*. Those features that are deemed to have contributed directly to the loss of the rig or its crew will be commented upon although greater detail will be provided in subsequent chapters.

The structure of the *Ocean Ranger* was similar to that of many other semisubmersibles operating in Canadian offshore areas and throughout the world. The rig consisted of two pontoons, eight vertical columns, an upper hull with two decks, and a supporting framework of braces and trusses. The two pontoons each contained 16 tanks that served as storage for ballast water, fuel oil and drill water. A pump room and propulsion room were located in the tapered section of the stern of each pontoon. Each pump room contained pumps, piping and valves associated with the pontoon tanks and bilge pumping system. Each propulsion room also contained two electric propulsion motors and their control panels as well as the hydraulic motors and controls for the steering system.

The pontoons were connected to the upper hull by eight watertight vertical columns. A structural framework of horizontal, vertical and diagonal braces connected and supported the upper hull and the port and starboard columns. In addition to giving structural support, greater stability and additional flotation, these columns provided space for equipment and storage, and routing for pipes, ducts and electrical wiring. All of the columns were fitted with ladders and watertight hatches giving access to intermediate decks and compartments. The stern columns each contained an elevator connecting the upper hull to the propulsion and pump rooms.

Each of the four corner columns contained three chain lockers for storage of anchor chains. These lockers lay between watertight flats at the 35-foot and 70-foot elevations. There were two upper deck openings leading into each chain locker; the first with an area of approximately 6 square feet at the top of the chain pipe, and the second with areas varying between 22.4 square feet and 28.3 square feet at the top of the wire box. These two openings were necessitated by the unusual combination of chain and wirerope used in the mooring system. The nature of this system also meant that the chain lockers were empty when the rig was moored at sea. The American Bureau of Shipping designated these openings as the "first point of downflooding", that is, the first point above the waterline where seas could enter the hull if the rig developed a severe trim or list. Nevertheless, there were no coverings provided for these openings, no drainage system in the chain lockers, no means installed for pumping out water and no alarm system to indicate if flooding did take place.

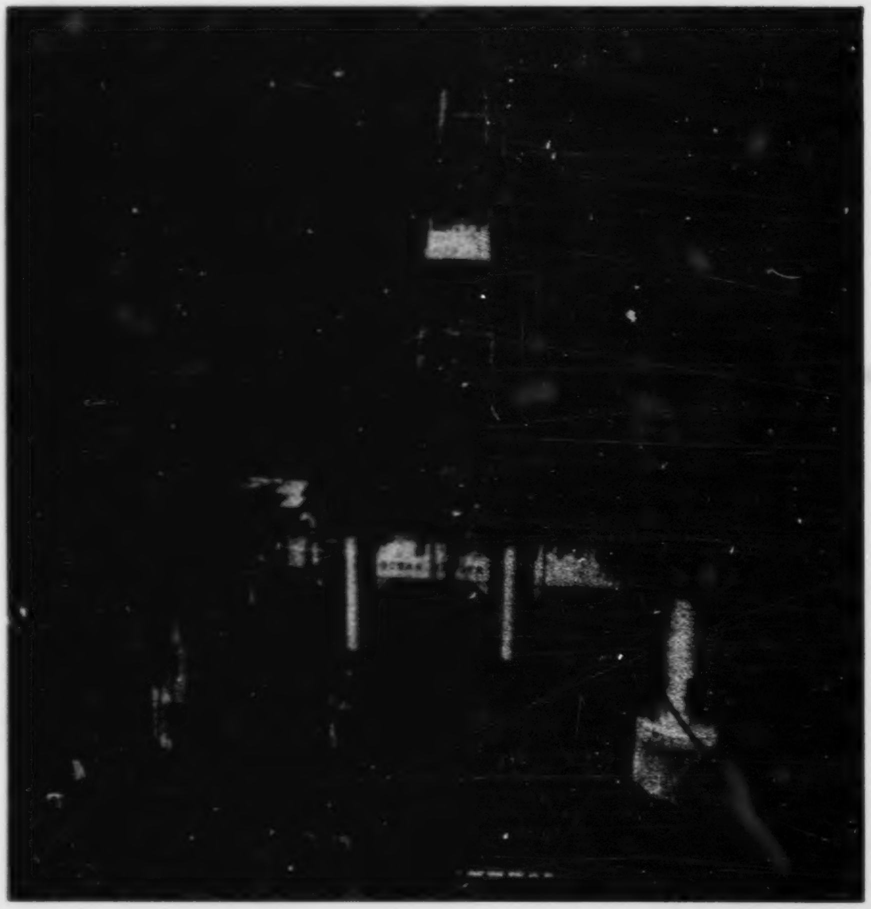

HELIDECK
(ACCOMMODATIONS
AREA BELOW)
DRILL
FLOOR
PILOT HOUSE
UPPER
DECK
UPPER HULL
BALLAST
CONTROL
ROOM
COLUMNS
AND BRACES
PUMP AND
PROPULSION
ROOMS
PONTOONS
TRANSVERSE
BRACE
BALLAST
TANK
CHAIN LOCKER

2.1 This illustration outlines the major structural components and working areas of the *Ocean Ranger*. The pontoons, 406 feet long, lay 80 feet below the surface when the rig was drilling.

The *Ocean Ranger* had a twelve-point mooring system with twelve 45,000 pound main anchors. Each anchor was attached to 1650 feet of 3¼-inch link chain, which in turn was connected to 5600 feet of 3½-inch wirerope. Three mooring lines extended from each of the mooring platforms on the four corner columns through fairleads to the anchors. These lines were controlled by winches positioned in groups of three on top of each of the four corner columns at the upper deck level. Control houses on the outboard side of these columns contained the equipment for operating the mooring system, in addition to instrumentation for monitoring anchor line tensions.

The four smaller side columns between the pontoons and the upper hull contained bulk storage tanks for dry drilling mud components. While three of those columns contained two storage tanks each, the third starboard column had only one tank with the space above it occupied by two control rooms. The ballast control room was situated at the 108-foot level above the keel and the control room for the mooring system lay directly above it.

The derrick and drill floor, at the centre of the rig directly over the moonpool, were surrounded by the upper hull which was divided into two major decks and an accommodations area. The lower deck, 134 feet above the keel, contained the primary and emergency electrical generators, air compressors, a machine shop, and



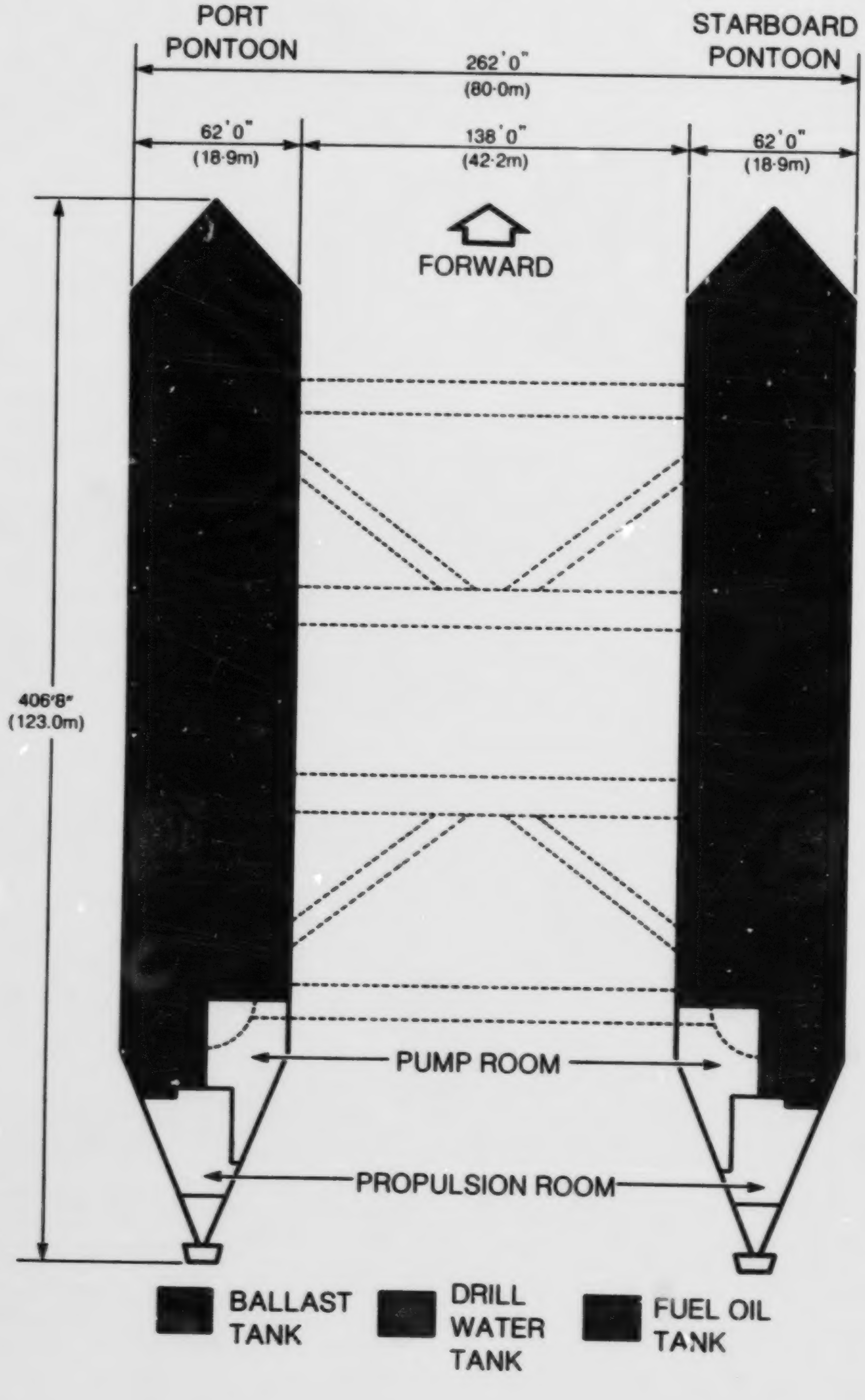
2.2 The *Ocean Ranger's* 12 anchor windlasses were replaced at the shipyard in Port Alberni, British Columbia, during 1979.

storage and handling areas for drilling mud and cement, as well as the first of the three accommodations levels. Two box girders divided the rig transversely into three sections, providing structural support for the drill floor and derrick. They also contained storage tanks for salt water, fuel oil, and drill water. An extensive piping system throughout the upper hull allowed the delivery of these liquids to the required locations. The upper deck served as a storage and handling area for the considerable quantity of supplies and material required to support the drilling operation. Three cranes were used to load material to and from supply boats and to handle it on board. Loading stations located amidships, port and starboard, provided piping connections for the transfer of liquid and bulk cargo. This upper deck, 151 feet above the keel, formed the roof of the lower deck, and the exposed top surface or weather deck of the upper hull.

The forward starboard corner of the upper hull provided crew's quarters on the first and second levels, and a radio room, hospital, offices and managers' quarters on the third level. The helicopter deck was located directly above the accommodations area, and the pilot house was situated forward of the accommodations, adjacent to the mooring platform on the starboard bow. The upper deck was designed to be watertight when in an undamaged condition. A severe bow trim, however, would expose several ventilators at the bow and the windows located in front of an unprotected stairwell in the forward port corner of the accommodations area to wave damage which could result in the flooding of the lower deck.

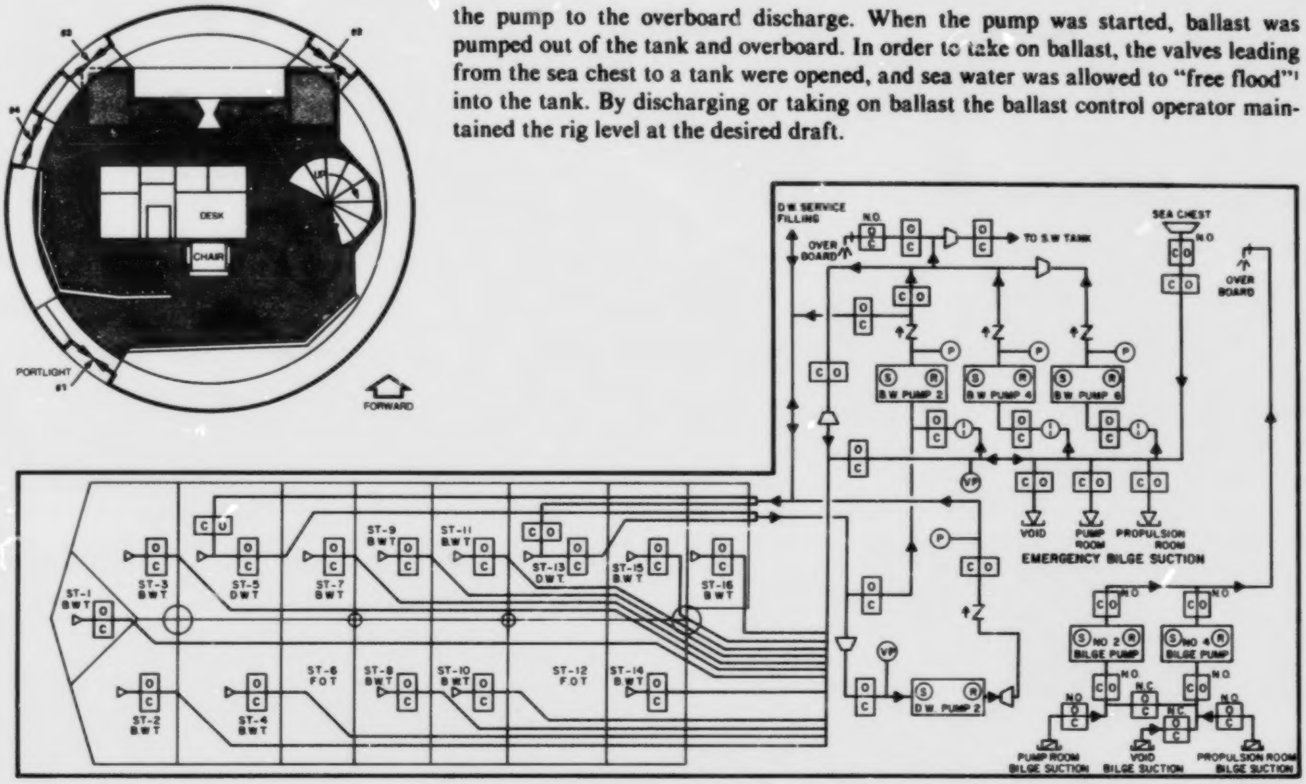
THE BALLAST SYSTEM

The ballast system on the *Ocean Ranger* consisted of three major components: the 24 ballast tanks in the pontoons; the 6 pumps used for ballast discharge; and the system of pipelines and remotely operated valves connecting the pumps and tanks. Ballast was discharged by opening the appropriate valves from a tank to a pump, and from


PORT PONTOON
STARBOARD PONTOON
262'0" (80·0m)
62'0" (18·9m)
138'0" (42·2m)
62'0" (18·9m)
FORWARD
406'8" (123.0m)
PUMP ROOM
PROPULSION ROOM
BALLAST TANK
DRILL WATER TANK
FUEL OIL TANK

2.3 Of the 32 pontoon tanks, 24 were used to store ballast water, with the remainder used to store drill water and fuel oil. The ballast control room was located in the column above starboard tanks 10-13.

the pump to the overboard discharge. When the pump was started, ballast was pumped out of the tank and overboard. In order to take on ballast, the valves leading from the sea chest to a tank were opened, and sea water was allowed to "free flood"[1] into the tank. By discharging or taking on ballast the ballast control operator maintained the rig level at the desired draft.


DESK
CHAIR
PORTLIGHT #1
FORWARD
D.W. SERVICE FILLING
OVER BOARD
N.O.
TO S.W. TANK
SEA CHEST
B.W. PUMP 2
B.W. PUMP 4
B.W. PUMP 6
VOID
PUMP ROOM
PROPULSION ROOM
EMERGENCY BILGE SUCTION
NO 2 BILGE PUMP
NO 4 BILGE PUMP
N.C.
D.W. PUMP 2
PUMP ROOM BILGE SUCTION
VOID BILGE SUCTION
PROPULSION ROOM BILGE SUCTION
ST-1 B.W.T
ST-2 B.W.T
ST-3 B.W.T
ST-4 B.W.T
ST-5 D.W.T
ST-6 F.O.T
ST-7 B.W.T
ST-8 B.W.T
ST-9 B.W.T
ST-10 B.W.T
ST-11 B.W.T
ST-12 F.O.T
ST-13 D.W.T
ST-14 B.W.T
ST-15 B.W.T
ST-16 B.W.T

2.4 The ballast control room, 18 feet in diameter, was approximately 28 feet above the mean water level at the 80-foot drilling draft. The valves and pumps in the ballast system were controlled from the mimic panel, which provided a clearly labelled schematic representation of the system's components. The starboard section of the mimic panel is illustrated.

There is no evidence of serious problems with the ballast system during the rig's six-year operating history. The system worked well when the rig was level; it proved problematic, however, when the rig was trimmed by the bow. At a relatively moderate bow trim the suction limits of the pumps located in the stern of each pontoon were exceeded and the pumps were incapable of discharging ballast from the forward tanks.[2]

The ballast system was operated from the control room in the third starboard column where the ballast control operators monitored the contents of the pontoon tanks and the stability, attitude and draft of the rig. They used the ballast control console to change the contents of the tanks as necessary and to transfer drill water into or from associated pontoon tanks, adjusting ballast at the same time to compensate for the shifting loads.

The circular ballast control room was fitted with four portholes[3] which allowed the operator to observe the activity of supply vessels during the transfer of cargo and to view the draft marks attached to the four corner columns. Indeed, the primary reason for locating the ballast control room in the column was to permit the ballast control operator to read the draft marks. The farthest of these draft marks was some 200 feet away from the ballast control room. Accurate visual reading of these marks

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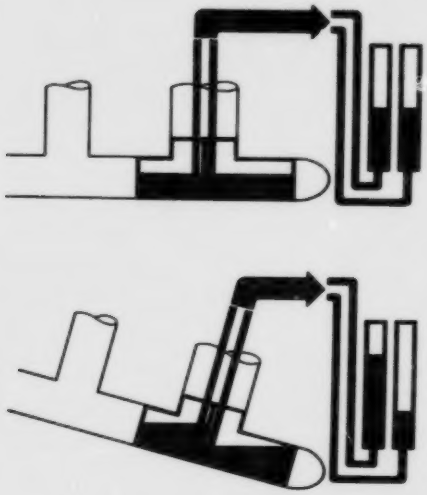
[1] Many semisubmersible owners follow the practice of pumping water into tanks, as this allows greater control. Free flooding is a very rapid method of filling a tank, and errors in operation can lead to unintentional changes in the rig's attitude.

[2] A more detailed description of the limitations of the system is provided in Chapters 6 and 7, and in Appendix F, Item 4.

[3] For the purposes of this report the term "porthole" refers to the circular frame surrounding a glass window, or "portlight". The ballast control room portlights were fixed in place and could not be opened. More technical information on the portlights will be found in Chapter 6.



2.5 An accurate assessment of the weight carried in each pontoon tank was critical for the stability calculation. Substantial errors would be encountered if the rig was trimmed, as the conversion tables made no allowance for the position of the gauge's sensor tube.

therefore was impossible in bad weather or heavy seas. Even with clear visibility the draft was estimated and subject to error. Because of the importance of maintaining the proper draft, an alternate and a more accurate method should have been incorporated into the rig's design. Remote reading gauges were commercially available when the rig was built and were used on many other contemporary semisubmersibles.

As the ballast control room was considered a dry area, the ballast control console was not protected from sea water. Each porthole did have on the inside a hinged metal cover or deadlight, which could be secured over the portlight to provide protection, but the normal practice was to leave these covers open. Even though the tempered glass was unable to withstand the pressures generated by waves predictable under extreme storm conditions, there was no protection provided for the console in case the portlight did break and sea water entered the room nor was the console itself designed to be watertight. In the event of accidental flooding by sea water the operation of the ballast control system could be affected.

Two sets of tank level gauges or "King gauges" located on the stern bulkhead of the ballast control room indicated the level of sea water ballast, fuel oil and drill water in the pontoon tanks. Conversion tables provided in the *Booklet of Operating Conditions*, were used by the ballast control operators in the calculation of the rig's stability. These conversion tables were accurate only when the rig was level and did not contain corrections to allow for trims to the bow or stern. The location of the King gauges' sensor tubes at the end, rather than at the centre, of each pontoon tank caused changes in the tank level readings when the rig was trimmed to the bow or stern. Therefore, the ballast control operator could misinterpret the tank contents when the rig was trimmed. Furthermore the gauges for the port pontoon were located on the starboard side of the ballast control room and the starboard gauges were on the port side. This confusing arrangement coupled with the possibility of misinterpreted tank contents could lead the operator to take inappropriate countermeasures to right the rig when it was trimmed.

In the centre of the ballast control room were the operator's desk, a video display terminal that showed the position of the rig in relation to the wellhead, and an environmental computer terminal that displayed information on anchor tensions, wind and wave conditions, and rig motions. The operator's desk also held a remote VHF radio and a handset for the public address system that allowed communication with other areas of the rig. In routine operations, the ballast control operator continually monitored two sets of inclinometers[4] which showed the rig's angles of trim and heel up to 15 degrees in each direction. If the angle increased past the desired condition, the operator would use the ballast control console to correct the attitude by discharging or taking on ballast.

The upper, vertical panel of the ballast control console contained instruments which monitored elements of the ballast, drill water, and fuel oil systems. Additional indicators showed the status (open/closed) of watertight hatches and doors in some of the other columns, and the status of the electrical and compressed air supplies to the control console. The lower, horizontal panel, referred to as the "mimic" panel, was divided into port and starboard sections etched with a schematic diagram representing the tank layout, piping, pumps and valves in each pontoon. Each valve was represented by a red and a green indicator light; red indicated a closed valve, and green indicated an open valve. These indicator lights were set in pairs of push-button switches, labelled "open" and "close", and the valve was operated by pressing the appropriate switch. In a similar manner, the pumps were each represented and operated by red "stop" and green "run" push-button switches containing indicator lights.

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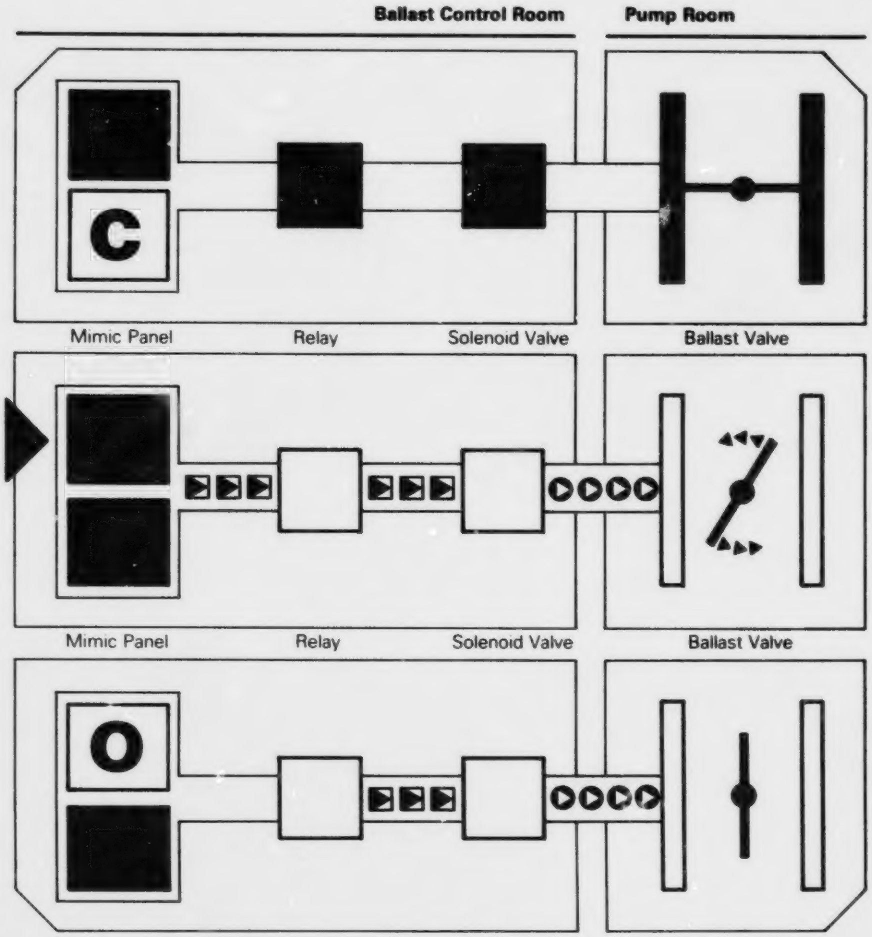
[4] Inclinometers were also found in the toolpusher's office, the radio room and the pump room.



VALVE CLOSED. The relay and solenoid valve are both in the unactivated position. A limit switch on the ballast valve actuator, connected to the indicator light through the relay, has illuminated the "closed" light.

OPEN SWITCH PRESSED. The "close" light is immediately extinguished as soon as the relay is activated. The ballast valve is in transit for 20-40 seconds. The failure of the valve to open, or to open completely, results in both indicator lights remaining extinguished.

VALVE OPEN. When the ballast valve is completely open a second limit switch on the valve actuator illuminates the "open" light.

2.6 Ballast control operation using the mimic panel.

▶ Electricity ● Compressed Air

The ballast control system was an "electric over air" type, using electric signals from the mimic panel switches to control the flow of compressed air that would open the valves in the pump room. When an "open" switch was pressed, a relay located behind the upper panel was electrically latched into an activated position. As current passed through the activated relay an electrically operated air valve (solenoid valve)[5] underneath the console was opened, and compressed air was directed to a piston and spring actuator on the remotely operated valve. Air entering the actuator caused the piston to move, compressing the spring and opening the valve. To close the valve, the "close" switch was pressed, causing the relay to return to the deactivated position and the solenoid valve to close. This allowed air to vent from the actuator on the remotely operated valve, thus allowing the spring to expand against the piston and close the valve.

The indicator lights on the mimic panel showed only that a valve was completely open or completely closed. When an "open" switch was pressed, the "closed" indicator light (red) was extinguished immediately by the relay, and for the 20-40 second period that the valve was in motion no indicator was lit. When the valve moved to the fully open positon, the "open" indicator (green) was lit. If both indicator lights remained extinguished for longer than 20-40 seconds, an *alert* operator would be aware that a malfunction had occurred somewhere in the system, although no alarms were installed to indicate where the malfunction had taken place.

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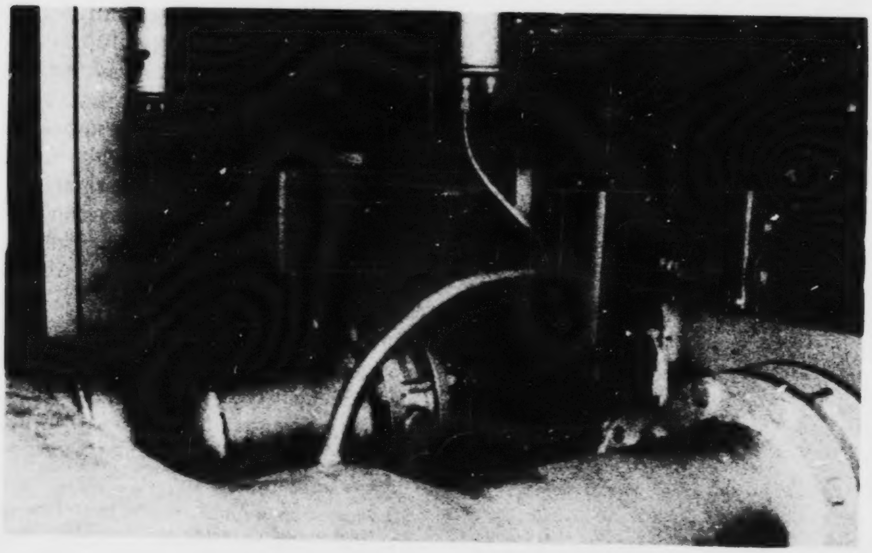
[5] Sixty-four solenoid valves, (one for each of the remotely operated valves in the pump rooms) and their associated wiring and tubing, were located underneath the mimic panel.

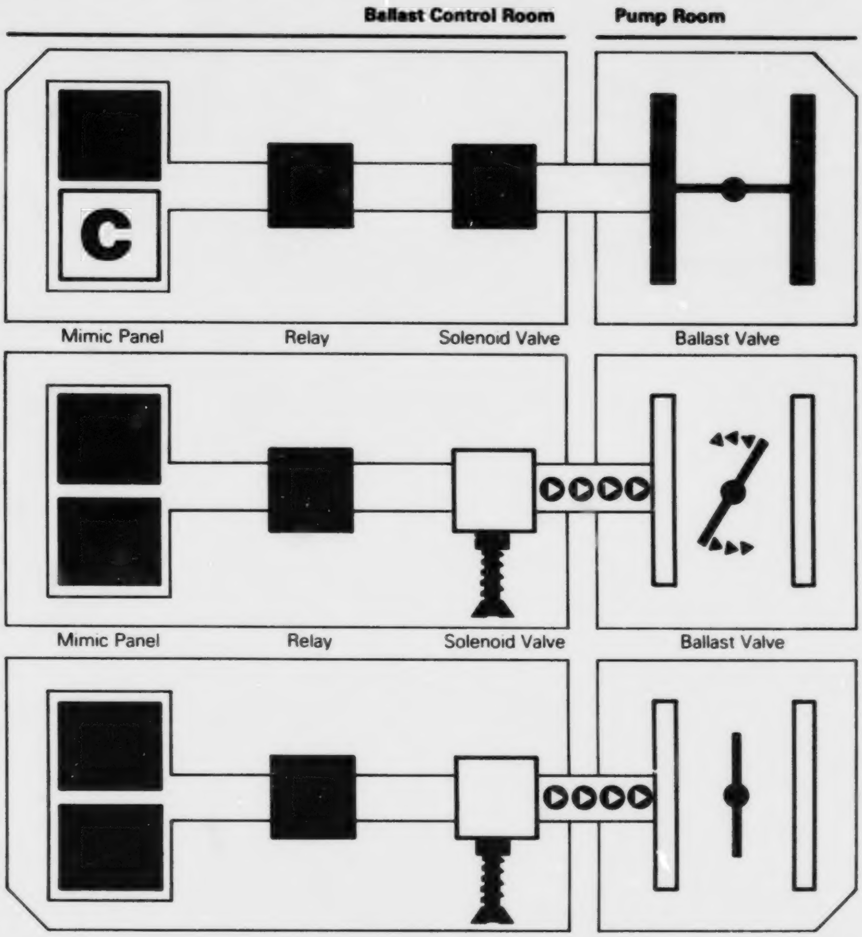
The mimic panel provided very limited information regarding the valves, and no information about the mechanical condition of the equipment. In the event of a mechanical failure in the valve control system, the operator could be presented with confusing or conflicting information. There was no method of ascertaining the direction of travel of the valves from the ballast control room. ODECO's original specifications did require a feature of this type but it was not included in the installed console.

If the supply of electricity or compressed air to the control console was lost, all remotely operated valves closed automatically. This "fail-safe" feature ensured that the valves would never be left open unintentionally if a power failure should occur. If power should be lost at the mimic panel, the ballast valves and pumps could be operated manually from the pump rooms. Each ballast valve could be opened or closed by turning a jackscrew on the valve itself. In each pump room, switches were provided to control the operation of the pumps. A manual ballasting operation using this method would have had to be co-ordinated from the ballast control room as the King gauges there were the only means available for determining the contents of the ballast tanks. As the public address system was the only method of communication available to the pump rooms, a failure in that system would have made manual ballast control operations from the pump rooms difficult.

ODECO ought to have realized the importance of providing a method of manually controlling the ballast valves from the ballast control room and incorporated this requirement in its contract specifications. It so happened that the resident electrician, representing the owners during the construction of the rig, knew that this could be done using the solenoid valves. The solenoid valves could be opened by inserting any device, the size of a pencil. By withdrawing the device the solenoid valve would close. He arranged for Mitsubishi to fabricate brass rods for this purpose which he used to test the pneumatic system before the electric control panel was installed. He also arranged for the brass rods to be stored in a box behind one of the panels of the control console. But there were no diagrams or instructions regarding the use of this method of manually controlling the valves from the ballast control room.



2.7 This photograph shows two of the remotely operated 18-inch butterfly valves in the pump room, which connected each ballast tank to the common manifold. Two other valves can be seen in the background, and the manifold is visible in the lower left-hand corner. These valves could be operated manually by using the threaded jackscrew at the top of the actuator.



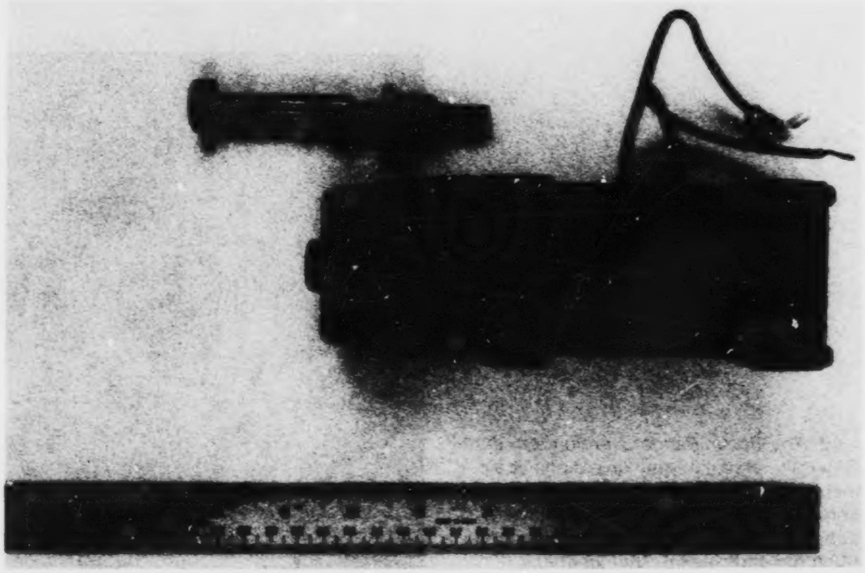
VALVE CLOSED. The relay and solenoid valve are both in the unactivated position. A limit switch on the ballast valve actuator, connected to the indicator light through the relay, has illuminated the "closed" light.

BRASS ROD INSERTED. The solenoid valve is manually activated, causing the ballast valve to open within 20-40 seconds. As the valve starts to move and releases the limit switch, the "close" light is extinguished.

VALVE OPEN. With the ballast valve fully opened, the 'open' light remains extinguished because the relay is in the unactivated position. Opening the ballast valve in this manner does not require electrical power to the mimic panel.

2.8 Ballast control operation using the brass rods.

▶ Compressed Air



2.9 The solenoid valve on the right is one of the 64 recovered from the wreck. The black protrusion at the front of the valve is a plastic dust cover inserted in a threaded opening. Although the valve was normally opened electrically using the switches on the mimic panel, it could also be opened manually by pushing the solenoid core with a tool inserted through this hole. The brass rod at the top is one of at least eighteen that were placed in the ballast control room, during construction, for this purpose.

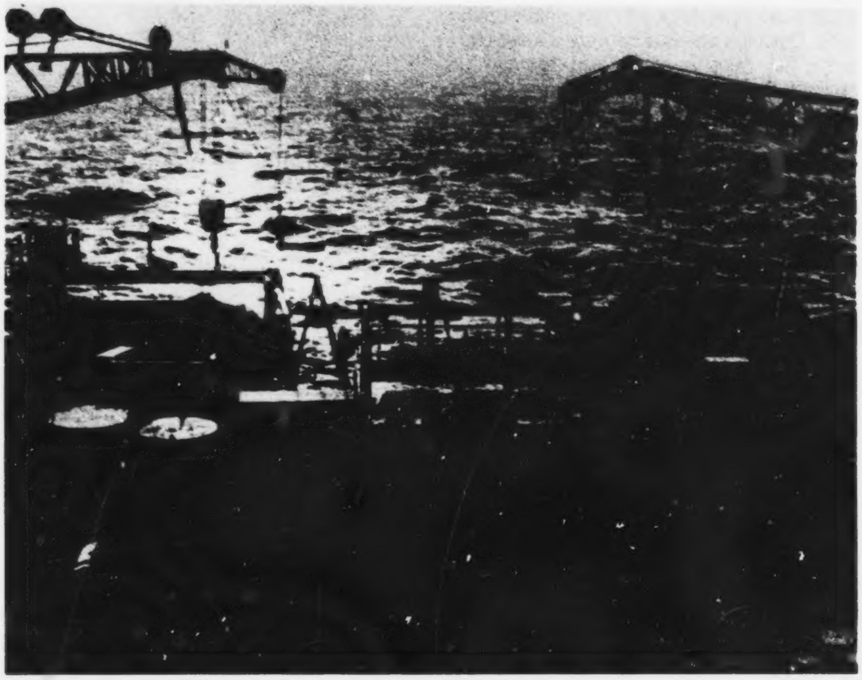
COMMUNICATIONS SYSTEMS

All drilling rigs engaged in offshore exploration maintain contact with shore bases, supply vessels, and other rigs while carrying out the drilling operation. The *Ocean Ranger* was equipped with a variety of systems for both external and internal communications. Several separate radio systems permitted the transmission and receipt of external communications by voice, telex, telegraph, and facsimile (Appendix D, Item 3).

The radio room, located on the third level of the accommodation area, contained the main HF radio unit, a marine VHF set, an aviation band VHF set, a wireless telegraphy system, and an automatic watchkeeping receiver for the 2182 kHz International Distress Frequency. The radio room was manned on a 24-hour basis by two ODECO-employed radio operators. Both Mobil and ODECO installed additional communications equipment to assist their personnel in conducting routine operations. Mobil installed a single side-band HF radio, with telex capability, in the radio room, and a remote transceiver in the Mobil drilling foreman's office. This radio was used by Mobil personnel to communicate with their shore base in St. John's and with Mobil personnel assigned to other rigs in the area. Mobil also installed two radio communications systems in its drilling foreman's office: a SPECTOR system and a Maritime Satellite (MARISAT) communications system. The SPECTOR system was an error-correcting device for telex transmissions and was capable of encoding data for security purposes. The MARISAT system provided an instantaneous satellite communication link (telephone, telex, and facsimile) from the rig to the worldwide commercial telephone and telex services. ODECO installed a single-side band HF radio set, similar to Mobil's, in the toolpusher's office to allow direct communication to ODECO's shore base in St. John's.

The *Ocean Ranger* was equipped with VHF radios in various locations, including the pilot house, ballast control room, cranes and the toolpusher's office. Marine VHF sets were used as a communication link with supply vessels. Handheld VHF sets were used by personnel on the rig to communicate with each other and with the supply vessels during the loading and offloading of cargo. A combined public address and intercom system was used for communicating on board the rig and for sounding the fire and abandon rig alarms. A sound powered telephone system, connecting many critical areas, was available as a back-up to the public address system. Surprisingly, no sound powered telephone was installed in the ballast control room.

2.10 The *Ocean Ranger's* radio room contained the primary communications equipment, installed in this console. The two inclinometers in the corner of the room were similar to those installed in the ballast control room and several other locations.



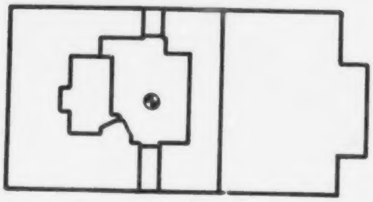
2.11 The stern of the *Ocean Ranger* showing the Harding (right) and Watercraft (left) lifeboats. A life raft station with three raft cannisters and a scramble net is located between the two boats. The white boxes beside each boat contained life preservers.

LIFESAVING EQUIPMENT

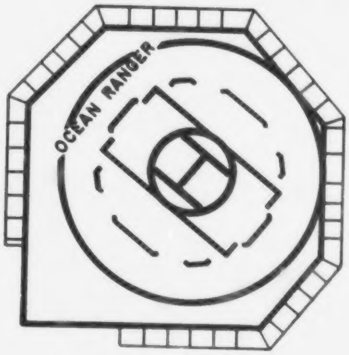
The primary lifesaving equipment included four totally enclosed fibreglass lifeboats, ten inflatable life rafts, 127 adult life preservers with lights and retro-reflective tape, 25 buoyant work vests, 15 life rings with lines, and an emergency position-indicating radio beacon (Appendix F, Item 6). When the *Ocean Ranger* was issued the *Certificate of Inspection* in 1979, the U.S. Coast Guard directed ODECO to ensure that the lifesaving equipment met their standards by replacing existing lifeboats and davits with U.S. Coast Guard approved equipment and by installing for 100% of the rig's crew davit-launched life rafts or an acceptable substitute. This directive was to be completed before the next inspection scheduled to take place on December 27, 1981. To comply with the second of these directives ODECO opted to install two additional 58-person lifeboats rather than davit-launched life rafts. At the time of the loss, however, although one of the new lifeboats was installed, it is not known whether it was provisioned and fully operable, and the other was stored on deck awaiting installation. ODECO had not replaced or changed the existing lifeboats and davits to comply with U.S. Coast Guard requirements (Appendix C, Item 5).

Lifeboats #1 and #2, built in Norway by Harding A/S, were located on the upper deck at the port bow and stern. Each had a 50-person capacity and was self-righting, in that it returned to an upright position if capsized, provided all personnel inside were secured by seatbelts and there was no damage and no significant accumulation of water inside. These boats were fitted with an "off-load" release mechanism which prevented the lifeboats from being released until they were waterborne. The Harding lifeboats were approved by Norwegian regulatory bodies. That these lifeboats were not approved by the U.S. Coast Guard does not mean that they were inherently unsafe or unfit for use during an evacuation, but merely that they were not manufactured according to procedures required by the U.S. Coast Guard. To receive U.S. Coast Guard approval a manufacturer is required to submit the design plans of the lifeboat for approval, after which the lifeboat has to be manufactured under the supervision of the U.S. Coast Guard.

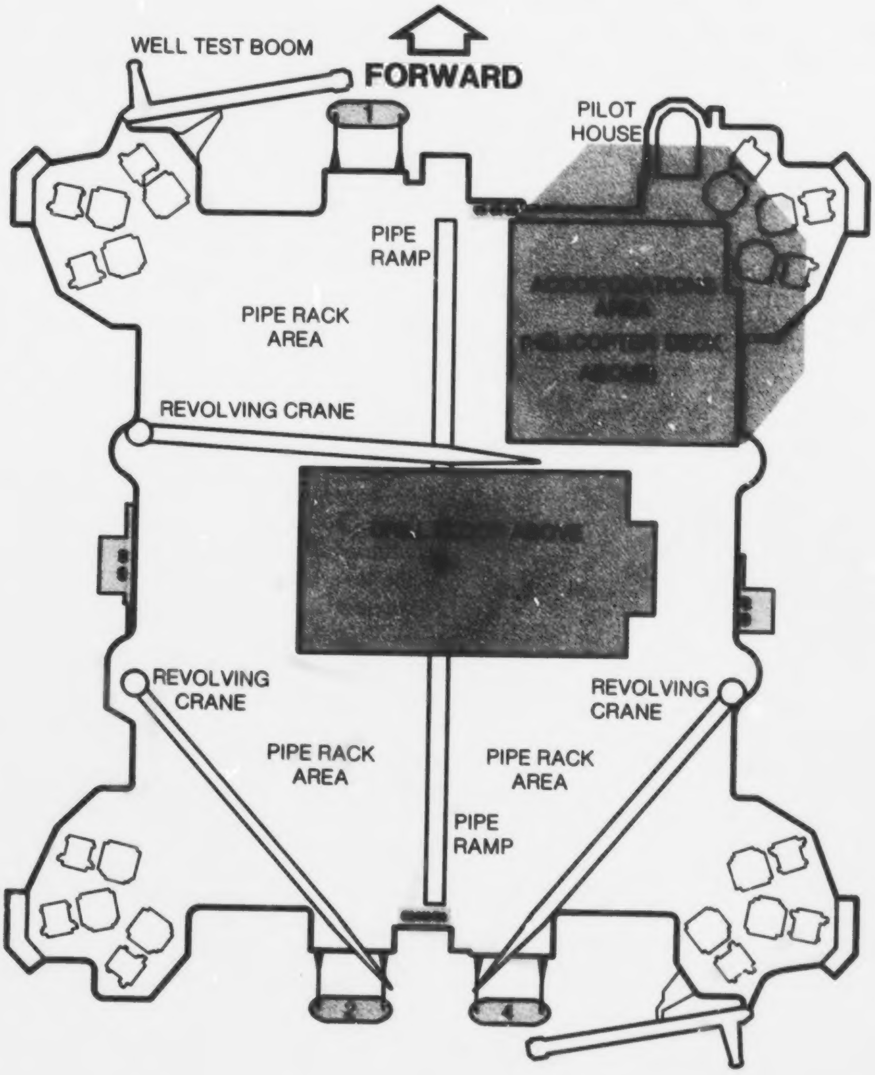
2.12 The upper deck was the main working area. Drill pipe and casing were loaded by crane from supply vessels, and stored in racks at the bow and stern. As drilling progressed, this material was moved to the drill floor along the pipe ramps and subsequently lowered into the well. The well test booms located at the port bow and starboard stern were used to flare gas and burn oil from the well during testing. At the time of the loss three lifeboats and ten life rafts were installed on this level; a fourth lifeboat was stowed on deck awaiting installation. Lifeboats #1 and #2 were 50-person Harding boats, while #4 was a 58-person Watercraft.



PLAN OF DRILL FLOOR


OCEAN RANGER

HELICOPTER DECK


WELL TEST BOOM
FORWARD
1
PILOT HOUSE
PIPE RAMP
ACCOMMODATIONS AREA
HELICOPTER DECK ABOVE
PIPE RACK AREA
REVOLVING CRANE
DRILL FLOOR ABOVE
REVOLVING CRANE
REVOLVING CRANE
PIPE RACK AREA
PIPE RACK AREA
PIPE RAMP
2
4

2.13 One of the Billy Pugh Model #200 life preservers recovered. The sea water-activated light that was attached to each life preserver is missing from the photograph.

The additional lifeboats were being installed at the time of the casualty. Lifeboat #3 was stowed on the upper deck awaiting installation and lifeboat #4 was installed on the starboard aft section of the upper deck awaiting inspection. These fibreglass lifeboats were manufactured by Watercraft America Incorporated of Edgewater, Florida. They were approved by the U.S. Coast Guard and were designed to be self-righting. The Watercraft boats were fitted with an "on-load" release gear which allowed release at any time during the launching sequence. The rig's muster list had not been altered to reflect the addition of one more lifeboat. It is not known whether the crew received instruction in the operation of the Watercraft lifeboats. Lack of proper instruction could cause confusion during an evacuation, since the release mechanism on the Watercraft lifeboats differed from that on the Harding lifeboats.

The ten, 20-person life rafts were positioned on the upper deck: four on the stern, two on the bow, and two on each side. All were manufactured in the United States. They were equipped with manual and hydrostatic release mechanisms and could only be entered from the water. These life rafts were inspected by IMP Group Limited (St. John's) in 1981. IMP was not a U.S. Coast Guard approved service centre for life rafts, nor was there an approved centre in Eastern Canada. (The nearest was in Boston, Massachusetts.) Minor deficiencies were found during this inspection and the life rafts were repaired before being returned to the rig. There was no evidence to indicate that these life rafts were used during the evacuation.

The method of deploying the life rafts from the rig required them to be thrown overboard and entered from the water. To get to the life raft the crew would have to climb down scramble nets located at each life raft station. In calm water and light wind this mode of escape may be practical; during storms life rafts deployed in this manner are generally impractical since high winds will blow an unoccupied raft away from the rig. Davit-launched life rafts would have been more useful as a means of escape. These life rafts, with crew members inside, are deployed in the same manner as lifeboats.

There were 127 Billy Pugh Model #200 life preservers which had been labelled as approved by the U.S. Coast Guard and 25 Billy Pugh Model WV0-100 work vests on board. The life preservers and work vests were positioned at various stations on the deck and in the crew's quarters. An unknown number of the life preservers was not, in fact, approved by the U.S. Coast Guard. These life preservers were sold by the manufacturer without receiving final approval.

As specified by COGLA, there were two types of immersion suits on board; insulated coveralls for crew members working in exposed areas of the rig and another type for use on helicopter flights to and from the rig. These immersion suits were not designed to offer protection against cold water and hypothermia. There were no regulatory requirements for marine evacuation suits (survival suits) although COGLA had previously suggested that all rigs and support vessels be equipped with survival suits. On July 7, 1981, some eight months before the loss of the *Ocean Ranger*, COGLA telexed all offshore operators stating that the loss of the *Arctic Explorer* and 13 of its crew members off northern Newfoundland highlighted the necessity of having survival suits on board and suggesting that they be provided (Appendix C, Item 6). But, as of February 1982, little progress had been made in carrying out this suggestion.

3

MANNING

CHAPTER THREE MANNING

Mobil Oil Canada Ltd. (Mobil), the operator for the consortium on the Hibernia Field, co-ordinated all aspects of its exploratory drilling program off the east coast of Canada from offices in St. John's, Newfoundland. These activities were the responsibility of the east coast manager. To carry out its drilling program, Mobil negotiated contracts with other companies for equipment and supplies such as drilling mud, cement and casing; services such as sea and air transportation to and from shore; and specially trained personnel such as divers, geologists and technicians. The largest contracts were with drilling contractors for rigs and their crews. In February 1980, Mobil entered into a contract with ODECO Drilling of Canada Ltd., a drilling contractor, for the *Ocean Ranger* and ODECO set up an office and a shore base in St. John's.

KEY PERSONNEL

The drilling operations and in fact all operations on the rig and even the rig itself, were under the control of the toolpusher, the senior ODECO man on the rig. All of the crew, except Mobil personnel and Mobil-contracted personnel, reported directly or indirectly to him. The toolpusher was appointed to his position of command after obtaining considerable experience in drilling operations. His training was on the job, learning by doing, supplemented with specialized short courses provided by his company, the industry or a training institution. The toolpusher on the *Ocean Ranger* on the night of the loss was Kent Thompson, a United States citizen, who had 15 years of drilling experience and had completed courses on blowout prevention, well control and rig management.

Closely associated with the toolpusher in his control of the drilling function was Mobil's drilling foreman; at least one was always on the rig. His responsibility was to represent Mobil's interests by monitoring the operations to ensure that the drilling program was completed as expeditiously and economically as possible. Possessing the authority to issue instructions to the toolpusher on drilling and industrial matters, he held considerable influence on the rig. The senior Mobil drilling foreman at the time of the loss was Jack Jacobsen, a Canadian citizen, with 16 years drilling experience. He had been an assistant superintendent with SEDCO for seven years before joining Mobil in 1980 as a drilling foreman. His training had been on the job, supplemented with courses in blowout prevention and applied drilling techniques.

The toolpusher's immediate subordinate in the drilling crew was the driller. He was the overall supervisor of operations on the drill floor and from a console located there he operated the drilling machinery and directed the activities of his crew which included a derrickman, several floormen, and a number of roustabouts. The derrickman was responsible for maintaining and repairing the equipment required to circulate the drilling fluid and the floormen were responsible for connecting the sections of drill pipe together to be run in and out of the well. In addition to helping with the drilling operation, roustabouts were required to conduct regular maintenance duties and assist the crane operator and the master during loading operations or when general marine maintenance was required.

> *Part 10.05-4(a) "The minimum service and experience required to qualify as applicant for license as a master of ocean mobile offshore drilling units . . . is (1) Four years' service as a roustabout, helper, roughneck, roustabout pusher, derrickman, crane operator, deck watchstander or the equivalent . . . Up to two of the . . . four years . . . service shall have been in a supervisory capacity . . . while so employed in such supervisory capacity an applicant must have performed all of such duties as . . . scheduling helicopter and boat deliveries and communications . . . directing operations of the unit, calculating and maintaining stability, exercise responsiblity for . . . maintenance of lifesaving and fire fighting equipment, maintenance of the unit in compliance with applicable government and company regulations . . . ."*
>
> *U.S. Coast Guard Code of Federal Regulations 46 CFR*

The master co-ordinated the marine aspects of the operations while the rig was moored on location. In order of seeming importance the master ranked third behind the toolpusher and the drilling foreman. He was not in command. He was responsible for the supervising and training of ballast control operators, for the loading of deck cargo, for the general marine maintenance of the rig and marine equipment and for the marine safety training of the crew. The master on board when the rig was lost was Captain Clarence Hauss, a United States citizen, who was assigned to the *Ocean Ranger* on a temporary basis on January 26, 1982, just 19 days before the casualty. He held a Master's licence (Unlimited, OCEANS) and for 15 years had been employed by Bethlehem Steel Corporation as a master and mate. When he joined ODECO in 1981, he was assigned to the *Ocean Victory* and the *Ocean Bounty* before joining the *Ocean Ranger*. During the 10 years prior to joining ODECO, he was not active as a mariner, but had worked as a stevedoring superintendent, as a technician in a detoxification centre and as a salesman.

Other members of the crew employed by ODECO performed dual functions which supported the rig both as a marine structure and as an industrial installation. They were the ballast control operators, electrical and mechanical personnel, crane operators, radio operators, the safety engineer[1] and the medic. The electrical and mechanical personnel and the ballast control operators played key roles in the sequence of events that led to the loss of the rig.

The electrical and mechanical systems were maintained by two electricians, an electronics technician, two motormen and two mechanics. They were responsible for conducting maintenance on the main engines, the emergency generators, the pumping and piping systems and the electrical and electronic equipment. They shared responsibility for the maintenance of the ballast control system but there was no single person on the rig who fully understood the function and operation of the entire system. The electricians were responsible for the maintenance of all electrical systems, the main generators, the emergency generators and all electrical aspects of the several control panels. They were required to check the ballast control console at least every 21 days to ensure that all lights, pump switches and solenoid valves were functioning properly. The senior electrician on board on February 15 was Thomas Donlon, a United States citizen, who had extensive experience as an electrician and had been on the *Ocean Ranger* since 1977. The junior electrician on board was Paul Bursey, a Newfoundlander, who had been employed for seven years as a marine electrician with Canadian National before joining ODECO and the *Ocean Ranger* in June 1981. The electronics technician was responsible for the public address system, the gas detection and fire alarm systems and the communications equipment. He would also assist the electricians whenever necessary. The electronics technician on board was Ted Stapleton, a Newfoundlander who had 15 years onshore experience before being employed by ODECO in 1981.

The rig mechanics were responsible for maintaining the mechanical systems, including the main engines and the valve actuators in the pumping system. The senior rig mechanic on board was George Gandy, a United States citizen, who had extensive experience in the drilling industry in the Gulf of Mexico, the North Sea and off West Africa. He joined ODECO in 1977 and was assigned to the *Ocean Ranger* on a regular basis in March 1980. He held an Ordinary Seaman's ticket issued by the U.S. Coast Guard.

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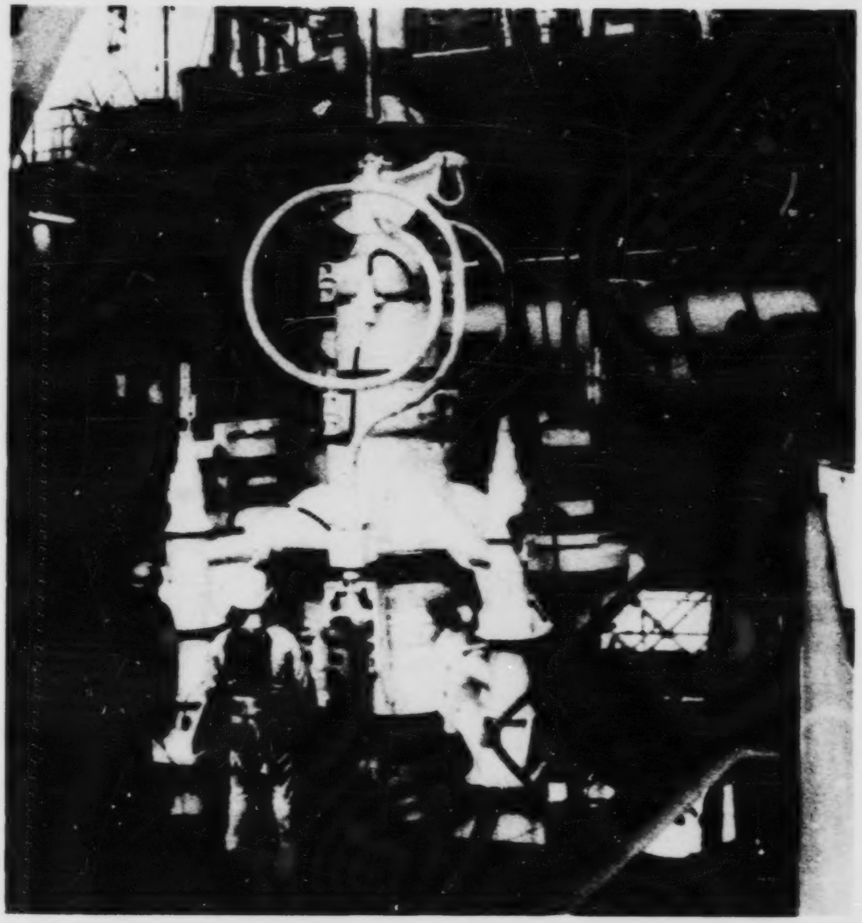
[1] This person is also referred to as the industrial relations representative.



3.1 This photograph shows the blowout preventer and marine riser being lowered to the seabed through the moonpool in the cellar deck. The blowout preventer is below the level of the deck, and the lower marine riser package and the riser connector are at the level of the two crew members in the foreground.

3.2 A welder at work on the slip joint, which is the primary element of the heave compensation system, and the point at which the marine riser connects to the rig. The worker is wearing a work vest and is secured by a safety belt and line.

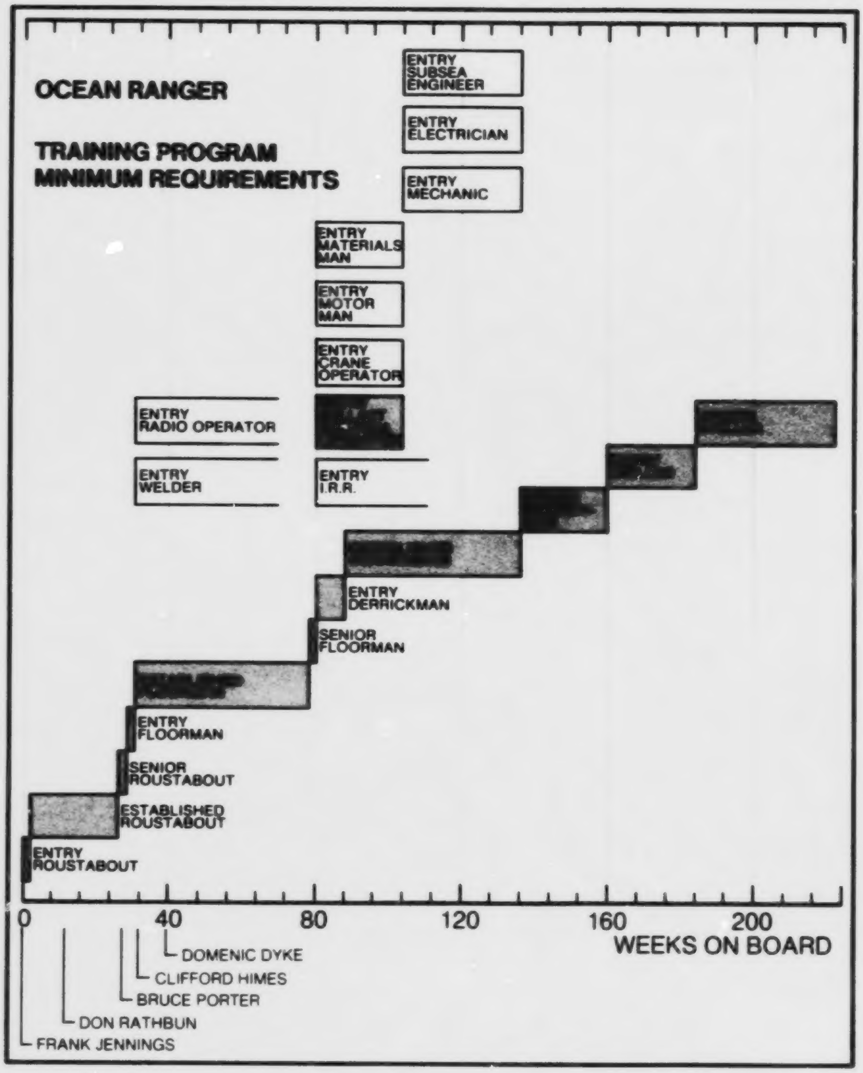
The ballast control operators were responsible for the operation of the ballast system. There were two on board the *Ocean Ranger*, each working a twelve-hour shift changing at noon and midnight. They were usually, but not always, relieved by the master during brief absences for meals and for routine inspections of the pump room or the deck. The role of the ballast control operators will be examined from several perspectives in different sections of the report. It is sufficient here to review their key function which was to maintain the stability, trim and draft of the rig and change its attitude by adding or removing ballast, as required by the drilling crew. They also monitored the tension on the 12 anchor lines.

The senior ballast control operator on the night of the loss was Donald Rathbun, a United States citizen, who joined ODECO as a roustabout in January 1980 with no previous drilling or marine experience. In March of that year he became a ballast control operator, learning through on-the-job training and private study. He had no formal training in his functions or responsibilities in the ballast control room. The junior and night ballast control operator was Domenic Dyke, a Newfoundlander, who before joining ODECO as a roustabout in December 1980, had worked with Crosbie Offshore Services as a deckhand on a supply vessel and with SEDCO as a roustabout. He was promoted to ballast control operator on December 31, 1981. He too learnt his functions and responsibilities through on-the-job experience and private study. He had several years of university education but received no formal training in ballast control operations. (Appendix D, Item 2 contains additional information regarding key personnel.)

ODECO TRAINING PROGRAM

The training policy and practice of ODECO reflected the general approach of drilling contractors in the oil industry; it emphasized on-the-job training, supplemented later with in-house courses for specific industrial duties. This policy was based on the conviction that it was advantageous to have inexperienced employees learn the required skills "from the bottom up." In this way they would understand "the company's way" of doing things and those with promise could be selected for appropriate training. The company could be confident that each employee had a minimum level of expertise required for the job and would have greater flexibility for transfers within the company. An inexperienced individual was hired as a roustabout, the general labourer in the oil industry. Through training on the job he could become familiar with the various activities on the drill floor and the general operation of the rig. In time and with experience he could be promoted to floorman and eventually to more senior positions, even to that of driller or toolpusher. In the course of this advancement he would, if selected, be provided with short courses in well control, blowout prevention, management and other related matters.

ODECO generally selected its ballast control operators from the drilling crew. If an individual showed the necessary interest and potential, he could train to become a ballast control operator. The stated training program of ODECO permitted a roustabout to train as a ballast control operator after 80 weeks' experience on the rig. After 24 weeks' training he could be placed in charge of the ballast control room. In practice, however, ODECO did not follow this policy. Three former ballast control operators gave evidence at the public hearings (Frank Jennings, Cliff Himes, Bruce Porter). Jennings testified that he responded to a newspaper advertisement and was appointed as a ballast control operator without any drilling or marine experience. After only several days of orientation he stood a normal 12-hour watch by himself in the ballast control room. Himes had 28 weeks, Porter had 32 weeks, Rathbun nad 12 weeks, and Dyke had 40 weeks of roustabout experience before being appointed to the ballast control room.



3.3 The ODECO training policy for the industrial crew required 80 weeks of experience before a crew member was recruited to train as a ballast control operator. This policy was not followed on the *Ocean Ranger*.

It is apparent that in practice the training of ballast control operators was at variance with ODECO's stated training program. The actual practice was to identify prospective candidates by the interest they expressed in training for the position. After he had completed his 12-hour shift the prospective candidate would be permitted to spend time in the ballast control room. No provision was generally made for him to work regular shifts as an understudy. When he had demonstrated to the experienced ballast control operator and to the master that he had the necessary skills and understanding to operate the mimic panel and to complete the daily calculations and the stability log, his appointment as a full-time ballast control operator would be recommended to the toolpusher. He would have had no courses nor would he have to pass tests, formal or informal, to determine whether he understood the system. The only requirements were an elementary understanding of how the system operated, the mechanical skill to operate the system through the use of the mimic panel, and the ability to make simple stability calculations. The training program did not provide an understanding of the electrical and mechanical operations of the ballast control system nor the effects of ballast gravitation. A thorough knowledge and understanding of what might go wrong and how to detect and remedy the situation were also lacking. The training emphasis was based on the erroneous assumption that the ballast system was fail-safe.

As mentioned in Chapter 2, there existed in the ballast control room, in a box behind one of the panels, brass rods which could be used to operate the ballast valves from the ballast control room without using the mimic panel. Why the existence of these rods was not more widely known, and why personnel were not instructed in their use has not been fully determined. Jennings, a former ballast control operator who served for some five and one-half years on the *Ocean Ranger* had no knowledge of their existence, let alone their purpose. During preliminary interviews conducted just after the loss, Himes, who was trained by him, had no knowledge of how the manual control system operated. Porter, who became a ballast control operator two months before the loss of the rig, testified that Rathbun told him that if a valve malfunctioned it could be operated from the ballast control room with the insertion of a manual control rod into the appropriate solenoid valve, located underneath the mimic panel. Porter produced a notebook compiled during his training period, to confirm that Rathbun's explanation was that when the rod was inserted, the malfunctioning valve would close. In fact, it would open. As 18 of these manual control rods were inserted on the night of the loss, this misunderstanding may have had serious implications. Had the ballast control operators understood the ballast control system, or had information about the manual control method been included in the *Booklet of Operating Conditions*, in a separate manual describing the console, or even in a drawing showing the details of the solenoid valves, the operators would have known how to operate the valves manually from the ballast control room.

"Should a valve become stuck open, you can close it manually by using the screw-wrench on far right side under console. Pull out black rubber plug in the offending valve (and) screw in valve."

Entry from Bruce Porter's notebook, Exhibit #136

During the period 1975 to 1978 ODECO provided formal training through a short three-day course in elementary stability theory for its ballast control operators, masters and barge engineers. The intention was to have all employees responsible for ballast control take this course. ODECO did not formally test course participants as job performance was seen as the real test of their understanding and knowledge. The ballast control operators on board at the time of the loss did not have the opportunity to take this course because it was no longer offered by ODECO when they were appointed to this position.

The U.S. Coast Guard, COGLA and the Petroleum Directorate did not specify in regulations or in guidelines the minimum training to be required of a ballast control operator. COGLA's regulations expressed in general terms that "they receive instruction and training in all operational and safety procedures that [they] may be required to carry out." COGLA did not have specific standards drawn up nor did it have any means of verifying the competence of ballast control trainees or of their instructors. In fact, neither COGLA nor the Petroleum Directorate appear to have taken much interest in the instruction or training of the crew.

Section 150 (1) "Every operator shall ensure that every person employed on a drilling program (a) receives instruction and training in respect of all operational and safety procedures that person may be required to carry out during the course of his duties during employment ..."

Canada Oil and Gas Drilling Regulations, November 1980

ODECO HIRING POLICY

In October 1980 ODECO submitted its proposed hiring and training program for the *Ocean Ranger* to the Government of Newfoundland. ODECO planned to hire 20 local residents as entry level floormen, radio operators and welders within 34 weeks, and then to replace 50% of the remaining crew with local residents thus filling approximately 60% of the total crew complement. After 104 weeks this percentage would be increased to 74% with local residents filling positions at the entry level of derrickman, ballast control operator, crane operator, motorman, materialsman and industrial relations representative (safety engineer). Within 182 weeks ODECO felt that 92% of its crew would be local residents through the addition of electricians,

3.4 Ballast control operators at work in the ballast control room. The photograph shows the confined working area in the room; an Aldis lamp, used for illuminating the draft marks at night, can be seen on the port section of the mimic panel in front of porthole #3. The handset for the rig-wide public address system is visible at the extreme left.

mechanics, subsea engineers and drillers. Local residents who had experience and qualifications above the level of roustabout would be assessed on their individual merits.

This policy reflected the industry's approach to training new employees who had no experience in offshore drilling. The procedure of having new employees learn from the more experienced personnel was commonly practised and local hiring was mutually beneficial to the host country and to the contractor. Since the efficiency and safety of the drilling contractor's operation depended upon the crew working as a unit, it was considered impractical for the drilling contractor to replace too many of the crew too quickly. This practice could increase the risk of accidents and through inefficient operations cost both the contractor and the operator money in lost drilling time.

Local hiring policies in Canada, as they were applied to the offshore drilling industry, were complicated at the time of the loss by the existence of a dual regulatory system. The Federal Government and the Provincial Government both had policies which applied to the offshore industry. The major difference between them was in the rate of phase in of local personnel. The policy of the Federal Government regarding local preference was formulated by the Department of Employment and Immigration and communicated to the offshore industry through COGLA. Essentially, the policy did not set specific local resident quotas but relied upon the industry to reduce over a reasonable period of time the percentage of non-resident workers. COGLA recognized that too rapid a phase in of inexperienced personnel could jeopardize the safety of the operations and of the personnel and reduce the efficiency of the drilling program.

The provincial policy did not appear to accept that practice or its rationale. *The Newfoundland and Labrador Petroleum Regulations* (1977) and the guidelines to those regulations, published November 30, 1978, specified the positions in which residents should be employed immediately, and the positions in which non-residents should be phased out over time. The cumulative effect of the Province's regulations

3.5 A Sikorsky S-61 on the *Ocean Ranger's* helideck during a crew change. This type of helicopter was used to transfer personnel and light cargo from St. John's to the Hibernia Field. During these flights all passengers wore immersion suits and inflatable life preservers.

and guidelines on local hiring preference required a drilling contractor to replace 44% of the crew immediately upon the arrival of the rig and an additional 21% of the crew within one month. After one month of operations the drill rig was expected to have replaced 65% of its crew with Newfoundlanders.

Correspondence between ODECO and the Government of Newfoundland indicates that the Provincial Government was not satisfied with ODECO's performance under the local preference regulation. ODECO contended that it would employ qualified local personnel in all positions on the rig but that inexperienced and unqualified workers would have to be trained before they could advance to senior positions. The disagreement was thus not over the principle of local preference but over the rate of its implementation.

The reaction of the Province's Minister of Labour and Manpower was to advise Mobil that ODECO was in breach of Newfoundland's Petroleum Regulations and to request that Mobil correct the matter.[2] Steve Romansky, Mobil's east coast manager, testified that Mobil did not exert any pressure on ODECO to hire unqualified personnel. He expressed his company's concern that the Province and the industry were defining a qualified worker in different ways. The industry felt that an offshore worker became fully qualified after a considerable amount of "hands-on" experience whereas the Province felt that previous offshore experience was not essential for most of the positions on a rig.

The controversy over local labour preference needs to be viewed in the context of the high level of unemployment in the province and the political pressures to maximize local involvement in offshore developments. Nevertheless, Provincial officials may have been overzealous in discharging their responsibilities. If a policy of local labour preference is to be implemented, a proper system for assessing the qualifications of those listed in the Offshore Employment Register ought to be established in consultation with industry. The rate of phase in of local residents ought to be controlled to ensure that acceptable standards of safety are not compromised. There is no evidence that the insistence upon the hiring of local residents caused or contributed in any way to the loss of the rig and its crew.

Page 12/13: ". . . drilling rigs operating off our coasts should not . . . use non-resident workers for any of the following positions . . . (1) roustabout, (2) maintenance worker, (3) welder, (4) cook, (5) medic, (6) cafeteria worker, (7) steward, (8) radio operator and 50% of the roughnecks . . . In addition, non-residents should normally be phased out of the following positions within one month from the date the rig moves into our waters: (1) roughneck (remaining 50% of), (2) watchstander, (3) maintenance supervisor, (4) motorman . . . ."

Guidelines and Procedures Under Certain Sections of the Newfoundland and Labrador Petroleum Regulations, November 30, 1978

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[2] Under Provincial regulations, the operator held permits to conduct exploratory drilling and was required to ensure its subcontractors complied with Provincial regulations.

COMMAND STRUCTURE

As mentioned in the Introduction, offshore exploratory drilling was regarded as essentially an industrial operation in a marine setting. The organization of command and responsibility on board the *Ocean Ranger* was very similar to that used in traditional land-based drilling operations. The crew structure reflected a predominant interest in an efficient industrial endeavour; the marine operations which ensured the stability and safety of the rig were relegated to a subordinate role, comparable to that of any other support group. This lack of attention to and emphasis on adequate marine practices was evident in the command hierarchy, in the provision of marine-qualified manpower, and in the training policies on board.

Part 109.109(a) "The master or person in charge shall-(1) Ensure that the provisions of the Certificate of Inspection are adhered to; and (2) Be fully cognizant of the provisions in the operating manual. . . ."

U.S. Coast Guard Code of Federal Regulations 46 CFR

Under the regulations of the U.S. Coast Guard the owner of a self-propelled MODU is required to "designate an individual to be master or person in charge of the unit" and the master or person in charge is required to ensure that "the provisions of the *Certificate of Inspection* are adhered to" and that he is "fully cognizant of the provisions set out in the operating manual." It was ODECO's policy to designate the toolpusher as the "person in charge" while the rig was moored on location. When the rig was lifting its anchors and was moving either under its own power or under tow to another site in the same field, the master became the "person in charge." If, however, it was moving from one Coastal State to another under its own power, an experienced "transit" master was sent to command the rig.

It is clear from the *Booklet of Operating Conditions* and from the evidence that Kent Thompson was in charge of the *Ocean Ranger* and that Captain Hauss was his subordinate. Thompson, however, had no marine qualifications even though in the event of an evacuation he was required to be in charge of one of the lifeboats. His knowledge of the sea and of rigs as marine structures was limited to his experience as a member of a drilling crew on a semisubmersible. He had no knowledge of the ballasting system or the principles of stability. And yet the ultimate authority and responsibility for the safety of the rig and its crew rested in his hands.

The participation of the Mobil drilling foreman in the control of the daily activities of the rig further confused the command issue. According to the contract between ODECO and Mobil, the Mobil foreman had the authority to issue instructions to the toolpusher on matters affecting the rig and the drilling operations. Since the drilling foreman represented the operator, his opinions would of necessity be given considerable weight but his instructions did not have to be followed by the toolpusher. Conflicts could therefore occur. An example of this arose during the period January 15-19, 1982, when a storm developed similar to the one encountered on February 14-15, 1982. At the time Mobil was testing a geological formation and though heaves exceeded allowable limits, Mobil requested that the hang-off and disconnect procedure be delayed. Don Leger, the toolpusher at that time, denied the drilling foreman's request and completed the process.

The role and responsibility of the master became evident from the testimony of the five former masters of the *Ocean Ranger* who appeared before the Royal Commission. The master was placed in the difficult position of having responsibility for marine matters without the authority to ensure that these responsibilities were properly discharged. His title belied his position. He had no marine crew under his direct and exclusive control. Even the ballast control operators for whom he was responsible took their orders regularly from the driller or toolpusher. The extent to which his advice on marine matters was sought or followed, depended upon his relationship with the toolpusher. The rig was simply a drilling platform and the master's presence on board the *Ocean Ranger* ensured compliance, if nothing else, with the requirements of the *Certificate of Inspection.*

ODECO provided a certificated mariner, Captain Hauss, as master although they did not provide him with training in the ballast control system, with a knowledge of the intricacies of that system as it affected stability, or with an orientation to the *Ocean Ranger*. The *Certificate of Inspection* issued by the U.S. Coast Guard for the *Ocean Ranger* was even less stringent than ODECO's practice, requiring only a master with an Industrial Licence while the rig was moored on location. That licence had no status under United States law or Coast Guard regulations.[3] It was developed specifically as a licence for personnel on semisubmersibles of United States registry. However adequate this licence may be deemed to be for a master of a rig operating in the Gulf of Mexico, it is unsuitable for a person who is in charge of a semisubmersible operating in the hostile environment of the Grand Banks or anywhere else in the Northwest Atlantic. Stormy weather, drifting pack ice or icebergs, or a combination of these conditions may require the rig to be moved at short notice. Weather conditions on the Grand Banks are such that little dependence can be placed upon the possibility of flying a qualified mariner to the rig to assume command in the event of such occurrences.

In contrast Norwegian regulatory authorities now require that the person in charge of a MODU operating on their continental shelf and on all Norwegian Flag rigs operating anywhere in the world be a qualified master mariner with training, both theoretical and practical, in the stability and the ballast control of MODUs as well as of conventional vessels and also in basic drilling techniques. They deem a MODU to be a vessel which must be operated according to recognized marine practices. In the United Kingdom, MODUs under British registry must be under the command of a master mariner (British license). Those of foreign registry are subject to the requirements of the flag state. The United Kingdom, however, does not require additional training in stability and ballast control for masters of its rigs.

MARINE TRAINING OF CREW

An aspect of the ODECO manning practice which indicates the secondary importance given to marine matters was the lack of a marine crew and of marine training on the *Ocean Ranger*. All of the crew who were ODECO employees, and even to some extent the master, were hired to support the primary activity of the rig, the drilling operation. The crew did not have, nor were they required to have, Marine Emergency Duties (MED) training. The *Certificate of Inspection* issued by the U.S. Coast Guard required, in addition to a master with an Industrial License, a marine crew consisting of two able seamen, one ordinary seaman and a sufficient number of certificated lifeboatmen to man the lifeboats. There appears to be some confusion regarding the number of lifeboatmen required because of the increase in the number of lifeboats. But whatever interpretation is placed on the regulations, whether the number required was 4, 6, or 8, (the U.S. Coast Guard Marine Board of Investigation interpreted it as 4), at the time of the loss, the *Ocean Ranger* was undermanned by a minimum of 3 certificated lifeboatmen and 2 able-bodied seamen. ODECO's stated operating policy was to ensure that an adequate number of its industrial crew would hold the marine licences required by the U.S. Coast Guard. In fact only one employee, the rig mechanic, had marine certification. The operations manager of ODECO based in St. John's testified that he relied upon the master to ensure that the U.S. Coast Guard manning requirements were met. He stated that maintaining

> *"1. For certification as a Platform Manager are required:*
> *1.1 Certificate of Competency . . . Master Mariner . . . and at least one year's practice in a senior post on a drilling unit.*
> *1.2 Other theoretical and practical education and training . . . and experience in maritime handling and navigation of platforms . . . ."*
>
> *Regulations dated 11 December 1981 concerning Certificates of Competence for Personnel on Drilling Units and Other Mobile Offshore Installations. Section 4.*

> *"1. The Platform Manager*
> *1.1 has the highest authority on board and is responsible for the stability and safety of the drilling unit . . .*
> *1.8 is responsible for preparing instructions . . . as well as ensuring regular supervision of the following important operations: Changes in ballast, changes in trim, dynamic positioning operations, operations of the anchor systems . . . ."*
>
> *Regulations dated 23 March 1982 concerning the manning of Norwegian drilling units and other mobile offshore installations. Section 4.*

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[3] The Industrial License has no definition or status in law or regulation. It was developed by The Coast Guard Marine Inspection Office in New Orleans, LA as a license for offshore oil field personnel employed on semisubmersible drilling rigs who passed the test administered by that office. Passing the test and obtaining the license is not a legal or regulatory requirement for employment on board a semisubmersible drilling rig as master. However, the Coast Guard accepts the Industrial License on self-propelled, semisubmersible drilling rigs in lieu of the normally required Unlimited Master License while such rigs are on location for the purpose of drilling. ***Marine Casualty Report: Mobile Offshore Drilling Unit*** Ocean Ranger, ***O.N. 615641, capsizing and sinking in the Atlantic Ocean on 15 February 1982, with multiple loss of lives:*** U.S. Coast Guard, 20 May 1983, p. 30, footnote 1.

the required number of marine crew was complicated by the high percentage of Canadians on board because Canadian marine certification was not accepted by the U.S. Coast Guard. No evidence was given, however, as to the number of Canadians with marine certification. In fact Canadian regulations did not require marine training or certificates for crew members employed on rigs operating offshore. The explanation given by ODECO's operations manager, who was responsible for selecting and hiring all new employees, was not persuasive.

4

OPERATIONS

CHAPTER FOUR OPERATIONS

This chapter will examine and comment on those aspects of the rig's operations which lie within the mandate of the Royal Commission. A prelude to the loss of the *Ocean Ranger* occurred just eight days earlier, on February 6, 1982, when the rig developed a sudden list because of a ballast control error made by the master. The implications of this event are significant and will receive comment.

The *Ocean Ranger* operated on a 24-hour basis, with two full drilling crews working 12-hour shifts. The drilling operations were supported by ancillary services which also operated on the 12 hour shift system. Generally the entire crew was relieved every 21 days. The shore-based offices of Mobil and ODECO received from their personnel a number of reports including a Morning and an Evening Report which were reviewed in St. John's and then forwarded to their respective head offices in Calgary and New Orleans. These reports were primarily related to drilling performance during the previous 12-hour period. ODECO's reports contained additional information about the rig's stability, the crew and weather conditions. In addition to the Morning and Evening Reports, which were generally sent by telex, the drilling foreman and the toolpusher communicated regularly with their shore bases, via radio or MARISAT, to discuss specific drilling problems with their supervisors.

To co-ordinate communications, ODECO generally employed a licenced radio operator and a second operator with a restricted licence who often doubled as a medic. Most communications occurred during the daytime shift (6:00 a.m. - 6:00 p.m.) while the licenced operator was on duty. The night shift (6 p.m. - 6 a.m.) was covered by the rig's medic. Generally communications on this shift were limited to personal calls by ODECO employees and were routed through the Canadian Coast Guard radio stations in Newfoundland and Nova Scotia where a phone patch was made to the party on shore. Radio operators were instructed by the toolpusher to monitor all calls to ensure that personnel did not relay confidential information.

The drilling operation was supported by air and marine resources provided by Mobil. Universal Helicopters Limited provided a ferry service between the rig and shore using three Sikorsky S-61 helicopters which were available to Mobil every day of the week on a 24-hour basis. Marine support was provided by two supply vessel contractors: Crosbie Offshore Services Limited and Seaforth Maritime Limited. Supply vessels were used extensively to assist the rig during transit, to deploy anchors once on site, to re-supply the rig with consumables and equipment and to transfer personnel when helicopters were not available. Supply vessels were also

Section 18. (1) "A suitable standby craft shall be provided for a drilling operation as a means of evacuating personnel from the drill site . . ."

Section 142. "Every person in charge of a standby craft referred to in section 18 shall . . . (b) maintain the craft within such distance from the drilling unit as is approved by the Chief . . ."

Canada Oil and Gas Drilling Regulations, November 1980

required to provide a standby service[1] to the rig to render assistance as required. All of these activities were the responsibility of Mobil's drilling foreman on the rig.

COGLA regulations required that a rig have a vessel assigned to it at all times primarily to render assistance as required. The regulations did not define the type of vessel, its standby role or distance from the rig while on standby duty. COGLA chose to let Mobil and the supply vessel owner determine the type of vessel and set an appropriate standby distance. The evidence indicates that on the Hibernia Field Mobil expected vessels to be within 1-2 miles of their assigned rigs during normal conditions and not more than 3-4 miles upwind during heavy weather. The contracts between Mobil and its supply vessel contractors, however, did not set out these requirements. The Petroleum Directorate did not have any regulations governing supply vessels.

Two trained weather observers[2] were on board at all times to collect environmental data according to standard meteorological procedures. Mobil received this environmental data every six hours and forwarded it to Newfoundland Oceans Research and Development Corporation Limited (NORDCO), their privately-contracted weather forecasting service in St. John's, and to the Atmospheric Environmental Service (AES) centre in Gander. The primary purpose for the data was to assist in the preparation of weather forecasts specific to the site of each drill rig operating on the Grand Banks. The NORDCO forecasts were updated every six hours and transmitted to the rigs via the Mobil shore base.

Confusion existed on the rig and at the shore base over the meaning of certain forecast parameters. Specifically, Mobil and ODECO personnel misinterpreted the definition of maximum wind speed. Michael Hewson of NORDCO testified that the forecast maximum wind speed referred to a sustained wind, not a gusting wind. Mobil and ODECO personnel interpreted it as gusts. This misinterpretation was significant because the operating limitations of the *Ocean Ranger*, as outlined in its *Booklet of Operating Conditions*, prescribed that the rig be deballasted when sustained winds exceeding 70 knots were forecast. If the crew had properly interpreted NORDCO's forecast, and adhered to the procedures outlined in the operating manual, the rig should have been deballasted on the afternoon of February 14, 1982, when sustained winds of 90 knots[3] were forecast. Deballasting would have increased the air gap between the upper hull and the seas which were forecast to occur later that day. As a result the portholes in the ballast control room would have been less susceptible to wave damage. NORDCO, Mobil and ODECO ought to have ensured proper interpretation by the crew of the *Ocean Ranger* of the terminology in the forecasts.

A qualified medic who doubled as the night radio operator was on board the *Ocean Ranger* at all times. Canadian regulations required that this person be a qualified physician, trained nurse, or medical attendent with a valid certificate. The evidence of a former medic and ODECO's shore-based physician shows that the rig had a well equipped sick bay and that routine medical treatment was adequately handled on board. Accident statistics reported from the *Ocean Ranger* at least during the

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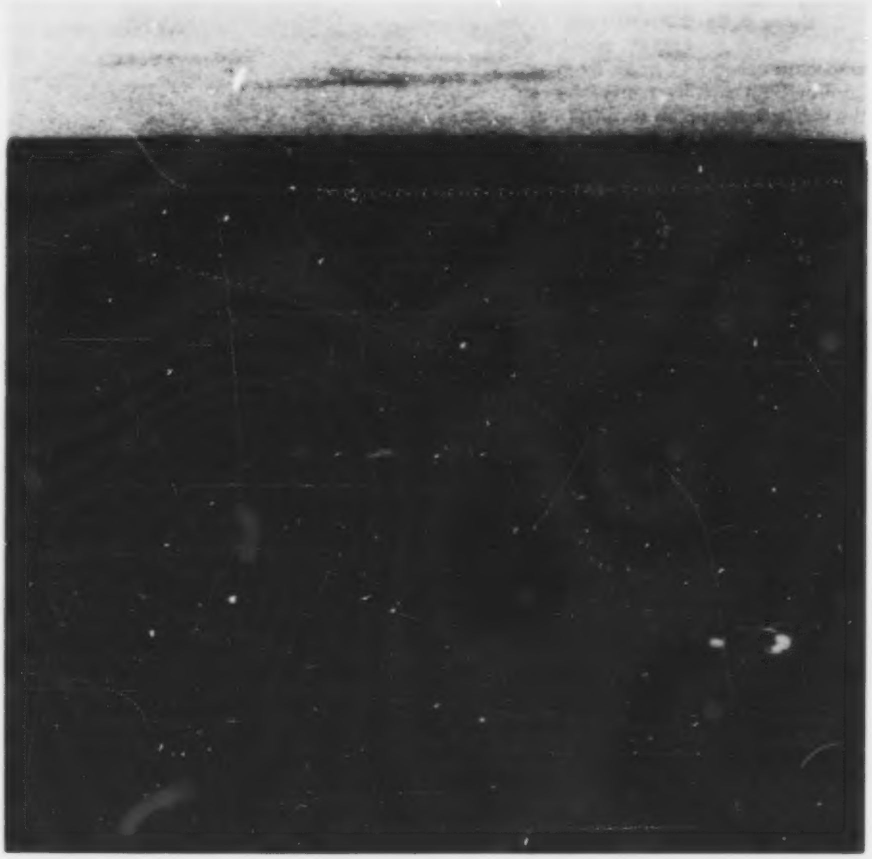
[1] Eastern Canadian offshore operators use supply vessels in a dual role – anchor handling/supply and rescue/standby. When a supply vessel has discharged its cargo it is generally assigned to a rescue/standby role.

[2] Weather observers received training from the Atmospheric Environment Service (AES) on environmental data collection. Their data was collected according to standards set out in the *Manual of Marine Weather Observing* (MANMAR) and *Private Aviation Weather Reporting Services* (PAWRS) manuals, supplied to the weather observers by AES. Appendix E contains information relating to weather forecasting and environmental conditions at the Hibernia site.

[3] The 90-knot sustained winds were at anemometer height (276 feet) whereas the 70-knot operating limit was for winds at the 10 metre (32.8 foot) level above the mean sea level.



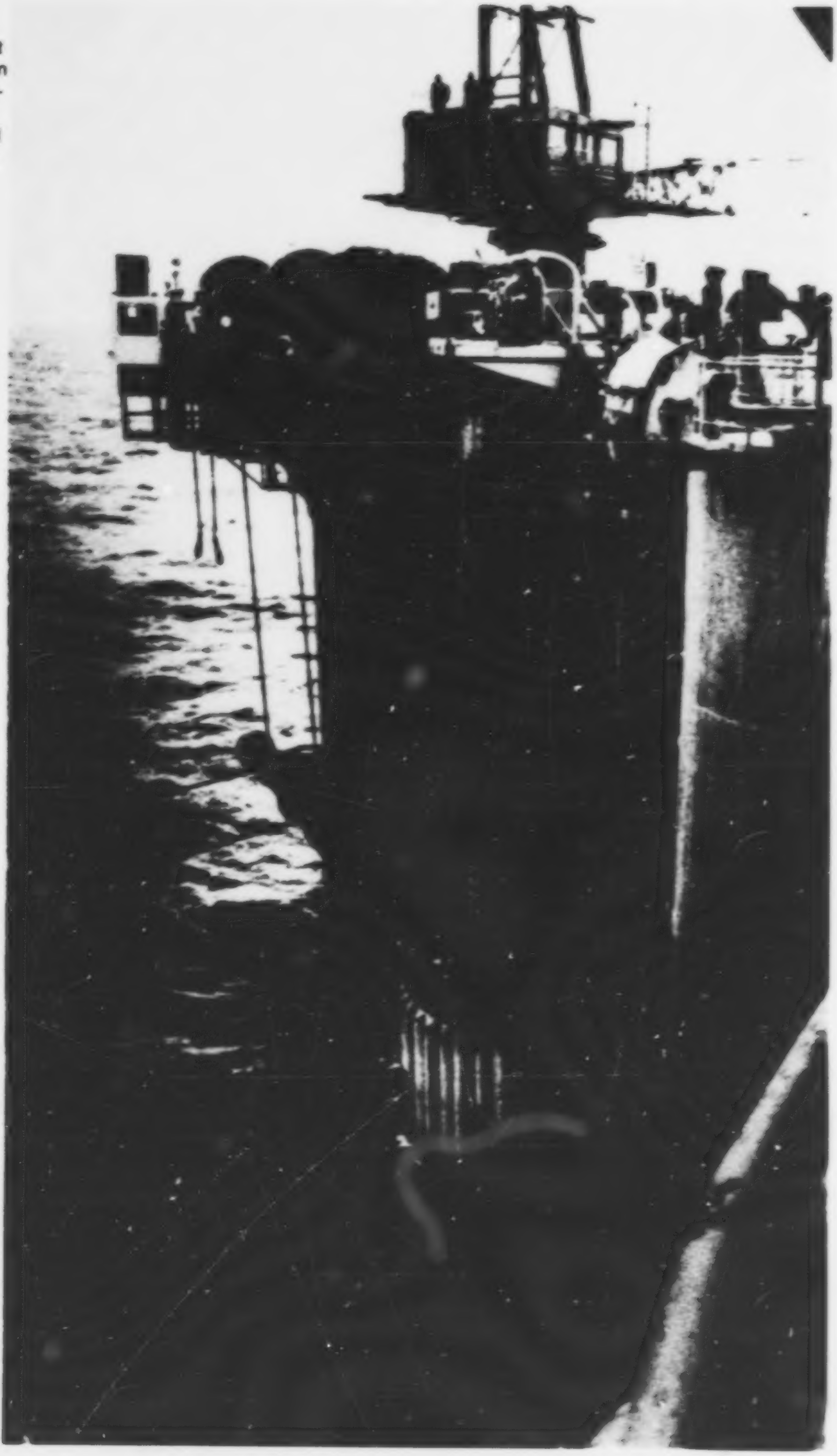
4.1 The *Ocean Ranger* with a Sikorsky S-61 on the helideck. The supply vessel *Ravensturm* is at close standby, as required during all helicopter operations.

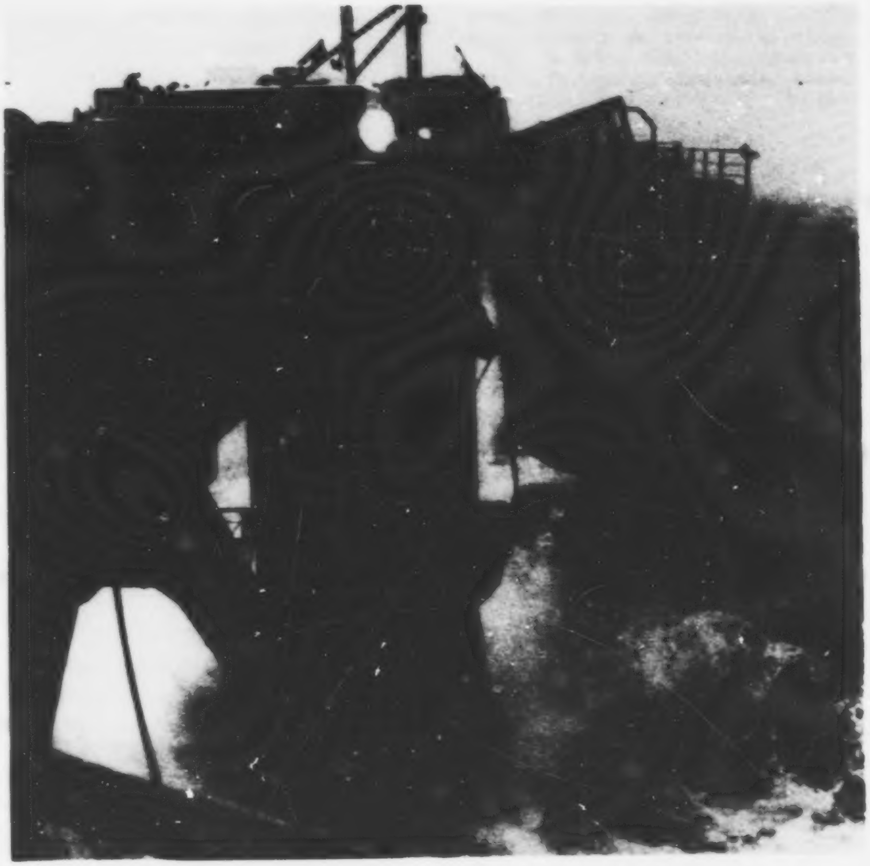
rig's last 12 months of operations do not reveal an abnormally high incidence of injury among the crew.

The ballast control operator maintained the rig at the attitude and draft required for the drilling operation. Acting on instructions from the drill floor, the operator added or removed ballast to give the rig a small degree of heel or trim. During the loading of consumables, the ballast configuration was altered to offset the effect of additional cargo. This function was crucial for safe operations; as one observer noted, "the ballast control operator alone of the crew, could sink a rig."

The *Booklet of Operating Conditions* identified specific tasks for the ballast control operators. Section K-2 stated that all valves should be opened daily and that all tanks were to be sounded weekly and the results compared with King gauge readings. Frequent stability calculations were required to determine whether the draft and variable deckload were within specified limits, and the weights of all cargo, equipment and tank contents were to be logged every two hours. According to the testimony of former ballast control operators this two-hour check was not carried out. Their evidence showed that weights recorded in the log were updated every 24 hours. The methods used to determine the weight and location of deck cargo were imprecise. Cargo weights were relayed to the ballast control operator based upon measurements taken by the crane operator, and actual weights were seldom checked against cargo manifests. Thus, the ballast control operator would, on the basis of experience, often estimate the cargo weight and use "inherited" weights for certain items to complete the calculation of the daily stability report (Appendix D, Item 4).

4.2 A view of the starboard side of the *Ocean Ranger*, looking aft from the first starboard column. Porthole #2 in the ballast control room is visible behind the catwalk on the third starboard column. The loading station for bulk liquid and dry cargo transfers can be seen amidships between the second and third columns. A similar loading station was located amidships on the port side.





4.3 The bow lifeboat station adjacent to the well test boom, seen from the first starboard column. The 50-person, Harding lifeboat was more than 70 feet above the sea surface when the rig was at the 80-foot draft. A second bow lifeboat station was to have been installed at the extreme left, and some preparatory work was already under way when this photograph was taken.

The resulting effect of inheriting weight inputs was reflected in the daily stability calculations. In fact, the ballast control operators paid little attention to the mathematical calculation of stability, preferring to use the inclinometers in the ballast control room to check whether or not the rig was level.[4] The stability report was sent to the master and toolpusher for approval, before being forwarded to shore base in St. John's and then to New Orleans. A review of actual reports and the testimony of former ballast control operators show that errors in calculation were not uncommon and were rarely picked up by supervisors either on board or on shore.

In addition, evidence was given that commencing in January 1982, the anchor tensions listed in reports were fabricated. The ballast control operators were told to record that all anchor tensions were within the 235 – 250 KIPS range. This evidence is supported by the report from Jacobsen on the night of February 14 that all of the anchor tensions were in the 240 KIPS range – an impossibility under the environmental conditions prevailing that night.

EMERGENCY PROCEDURES

COGLA regulations require each operator to develop a contingency plan for any foreseeable emergency that might develop during the drilling program. In August 1980, Mobil submitted for approval its *Contingency Plan and Emergency Procedures Manual for East Coast Operations*. Designed as a guide for company

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[4] Ballast control operators were primarily concerned about one variable in the entire stability calculation - the longitudinal metacentric height or GM_L. They were instructed that the calculated GM must be positive and greater than 1.5 feet. Imprecise weight inputs could result in errors in the GM calculation.

Section 79 (1) "Every operator shall ensure that contingency plans have been formulated and that equipment is available to cope with any foreseeable emergency situation during a drilling program . . . ."

Canada Oil and Gas Drilling Regulations, November 1980

employees at all levels to mobilize and co-ordinate personnel, communications and resources in emergencies, the ***Plan*** specified guidelines and procedures to be followed in the event of an oil spill, icebergs, pack ice, stormy weather, icing of superstructures, blowouts, anchor release, loss of a supply vessel or crash of a helicopter. It did not provide for contingency procedures for evacuation of the rig stating instead:

> It is not Mobil's intent to run the operation from a shore location. Wherever possible on-site personnel are expected to keep shore-based staff involved in the decision making process to ensure the best possible decision is made. In emergency situations the drilling foreman, barge captains and rig toolpushers will confer together and formulate the best possible plan to alleviate the situation. They will notify their respective superiors at the first opportunity.

The ***Plan*** set environmental limits for drilling and specified when hanging-off and disconnecting should be undertaken. It stated as a "generality" that:

> on a drilling unit capable of being operated as a vessel, the barge captain has the responsibility at all times for the safety of the vessel under his charge and all the people on it. In situations of imminent threat of severe damage to or loss of the contractor's drilling unit, his authority supercedes that of all other on-site personnel.

There was no copy of the ***Plan*** on board the *Ocean Ranger* and there was no evidence to indicate that ODECO personnel either on shore or on the rig were familiar with its contents.

ODECO had a manual entitled *Emergency Procedures*. Its objective was to:

> provide ODECO's toolpusher with guidelines for procedures in case of severe emergency. It is recognized that every situation will require to be dealt with in accord with conditions prevailing at the time and that those persons in command will have to use their initiative on action to be taken.

"The Drilling Foreman is Mobil's on-site representative . . . In emergency situations, the Drilling Foreman, Barge Captain and Rig Toolpushers will confer together and formulate the best possible plan to alleviate the situation . . . ."

Contingency Plan and Emergency Procedures Manual for East Coast Operations (Mobil)

"Odeco's Toolpusher has overall responsibility for all personnel safety and safety of the drilling unit . . ."

Emergency Procedures: Ocean Ranger Section 2 (ODECO)

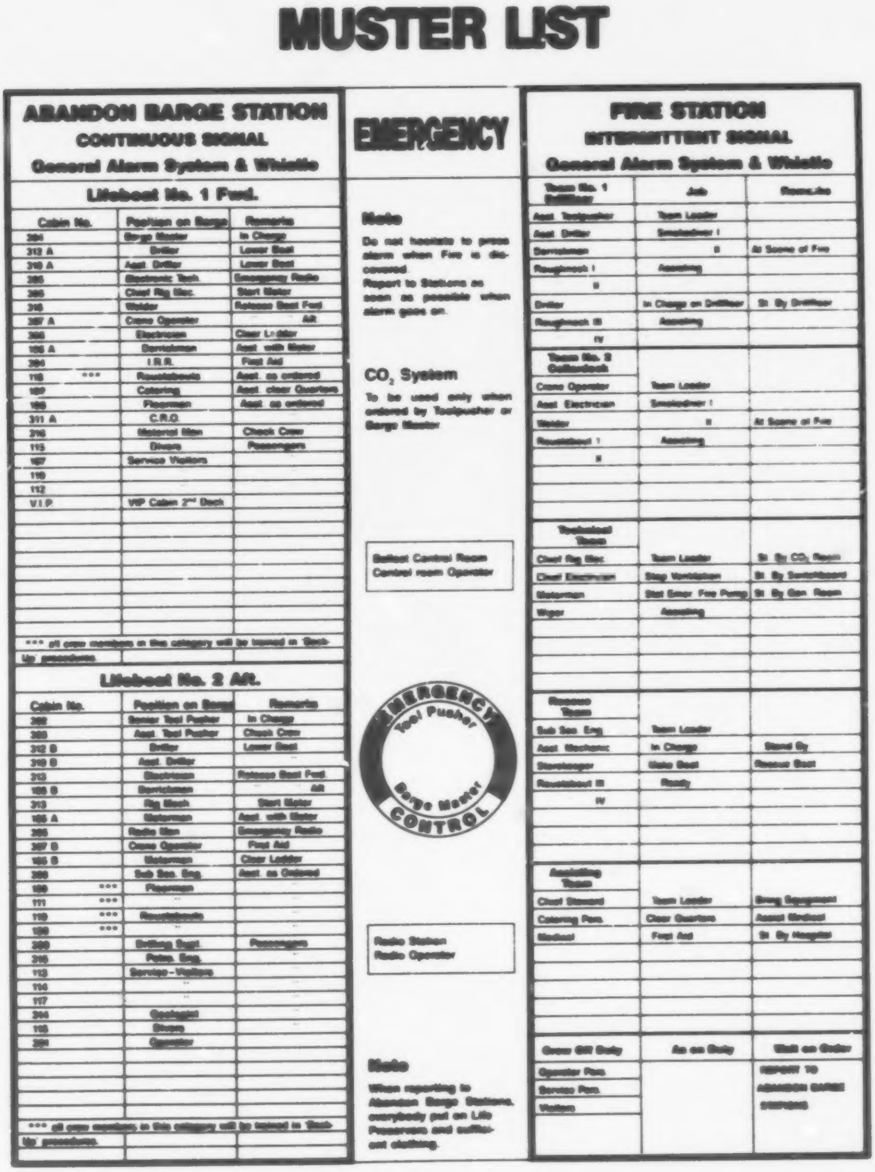
Included were provisions covering safety drills, man overboard and rig evacuation as well as environmental dangers arising from storms, pack ice and icebergs. It also included operational contingencies for fire, blowout, anchor failure, collision and helicopter emergencies. It contained procedures to be followed during severe storms emphasizing the cessation of drilling, hanging-off, disconnecting and evacuation. According to the manual, the toolpusher remained in charge and was responsible for giving the order to abandon the rig. The significance of this *Emergency Procedures* manual is uncertain, since one senior toolpusher, who left the *Ocean Ranger* in January, 1982, testified that he had never seen it. ODECO had no emergency procedures manual for onshore personnel.

A comparison of the Mobil and ODECO contingency plans shows several procedural inconsistencies, differences in criteria for the cessation of drilling, and disagreement over the person in charge. It is evident that there needs to be a co-ordinated contingency plan between the rig owner and the operator as well as between industry and government authorities. The details of these plans must be familiar to those in charge of their implementation.

EMERGENCY TRAINING

Both the U.S. Coast Guard and COGLA had specific regulations for emergency training but the Petroleum Directorate had none. These regulations did not specify the content of the emergency training required but dealt only with the frequency of drills to test the emergency response system. COGLA, for example, required weekly drills for "abandon ship", blowout prevention and fire. COGLA's inspectors, however, appear to have been more concerned whether the existing emergency systems were operable than whether the systems themselves and the training given to the crew were adequate. The U.S. Coast Guard regulations required regular testing of lifesaving and fire fighting systems and the assignment of specific duties to members of the crew during drills. Their two-year inspection interval, however, was too long to enable them to test either the effectiveness of the system or the adequacy of the marine safety training of the crew.

On the *Ocean Ranger*, emergency drills were conducted on Sundays between 12:00 noon and 1:00 p.m. These drills were co-ordinated by the toolpusher, the master, and the safety engineer. Each week, at the appointed time, the general alarm was sounded and all off-duty and non-essential crew members were mustered at lifeboat stations. The crew were required to come to lifeboat stations in accordance with assignments given in the muster lists which were posted in all cabins and at other locations throughout the rig. According to the muster list, the master was in charge of Lifeboat #1 and the toolpusher was in charge of Lifeboat #2. Certain members of the crew of the lifeboat were assigned special duties such as starting the motor,



MUSTER LIST

ABANDON BARGE STATION
CONTINUOUS SIGNAL
General Alarm System & Whistle

Lifeboat No. 1 Fwd.

Cabin No.	Position on Barge	Remarks
304	Barge Master	In Charge
312 A	Driller	Lower Boat
310 A	Asst. Driller	Lower Boat
305	Electronic Tech.	Emergency Radio
306	Chief Rig Mec.	Start Motor
316	Welder	Release Boat Fwd.
307 A	Crane Operator	Aft
308	Electrician	Clear Ladder
105 A	Derrickman	Asst. with Motor
304	I.R.R.	First Aid
116 ***	Roustabouts	Asst. as ordered
107	Catering	Asst. clear Quarters
108	Floorman	Asst. as ordered
311 A	C.R.O.	
316	Material Man	Check Crew
115	Divers	Passengers
107	Service Visitors	
110		
112		
V.I.P.	VIP Cabin 2nd Deck	

*** all crew members in this category will be trained in Jack-Up procedures.

Lifeboat No. 2 Aft.

Cabin No.	Position on Barge	Remarks
302	Senior Tool Pusher	In Charge
303	Asst. Tool Pusher	Check Crew
312 B	Driller	Lower Boat
310 B	Asst. Driller	"
313	Electrician	Release Boat Fwd.
105 B	Derrickman	" Aft
313	Rig Mech.	Start Motor
105 A	Motorman	Asst. with Motor
305	Radio Man	Emergency Radio
307 B	Crane Operator	First Aid
105 B	Motorman	Clear Ladder
306	Sub Sea. Eng.	Asst. as Ordered
108 ***	Floorman	"
111 ***	"	"
110 ***	Roustabouts	"
120 ***	"	"
300	Drilling Supt.	Passengers
316	Petro. Eng.	"
113	Service-Visitors	"
116	"	"
117	"	"
314	Geologist	"
115	Divers	"
301	Operator	

*** all crew members in this category will be trained in Jack-Up procedures.

EMERGENCY

Note

Do not hesitate to press alarm when Fire is discovered.
Report to Stations as soon as possible when alarm goes on.

CO_2 System

To be used only when ordered by Toolpusher or Barge Master.

Ballast Control Room
Control room Operator

EMERGENCY
Tool Pusher
Barge Master
CONTROL

Radio Station
Radio Operator

Note

When reporting to Abandon Barge Stations, everybody put on Life Preservers and sufficient clothing.

FIRE STATION
INTERMITTENT SIGNAL
General Alarm System & Whistle

Team No. 1 Drillfloor	Job	Remarks
Asst. Toolpusher	Team Leader	
Asst. Driller	Smokediver I	
Derrickman	II	At Scene of Fire
Roughneck I	Assisting	
II		
Driller	In Charge on Drillfloor	St. By Drillfloor
Roughneck III	Assisting	
IV		
Team No. 2 Cellardeck		
Crane Operator	Team Leader	
Asst. Electrician	Smokediver I	
Welder	II	At Scene of Fire
Roustabout I	Assisting	
II		
Technical Team		
Chief Rig Mec.	Team Leader	St. By CO_2 Room
Chief Electrician	Stop Ventilation	St. By Switchboard
Motorman	Start Emer. Fire Pump	St. By Gen. Room
Wiper	Assisting	
Rescue Team		
Sub Sea. Eng.	Team Leader	
Asst. Mechanic	In Charge	Stand By
Storekeeper	Make Boat	Rescue Boat
Roustabout III	Ready	
IV		
Assisting Team		
Chief Steward	Team Leader	Bring Equipment
Catering Pers.	Clear Quarters	Assist Medical
Medical	First Aid	St. By Hospital
Crew Off Duty	**As on Duty**	**Wait on Order**
Operator Pers.		REPORT TO ABANDON BARGE STATIONS
Service Pers.		
Visitors		

4.4 The muster list on the *Ocean Ranger* had not been altered to assign crew members to the newly-installed stern Lifeboat #4.

checking radio equipment, lowering and releasing the lifeboat, and verifying the passenger lists. Though it was not specified, the person in charge of the lifeboat was presumably responsible for all activities on the lifeboat during drills or emergencies, including manning the helm. It has already been mentioned that the toolpusher was not a certificated lifeboatman and it is difficult to understand how, in the event of evacuation, an untrained person could take command of and operate a lifeboat, particularly in severe sea conditions.

Several former crew members gave evidence on the emergency training received while on board the *Ocean Ranger*. Most were satisfied with the type of training they received. A former master, Captain Karl Nehring, however, testified that he was particularly concerned about the marine safety training and considered the routine evacuation drills to be so inadequate that he gave instruction on lifeboat operating procedures to small groups of crew members during their off hours. He stated that his primary concern was that crew turnover and irregular shift changes often meant that there were not enough crew members on board with marine training and he doubted whether an evacuation could be carried out properly. Other masters were also critical of the marine safety training, stating that lifeboats were rarely lowered to the sea during drills, even though U.S. Coast Guard regulations required that lifeboats be lowered to the water, released, and operated at least once every three months.

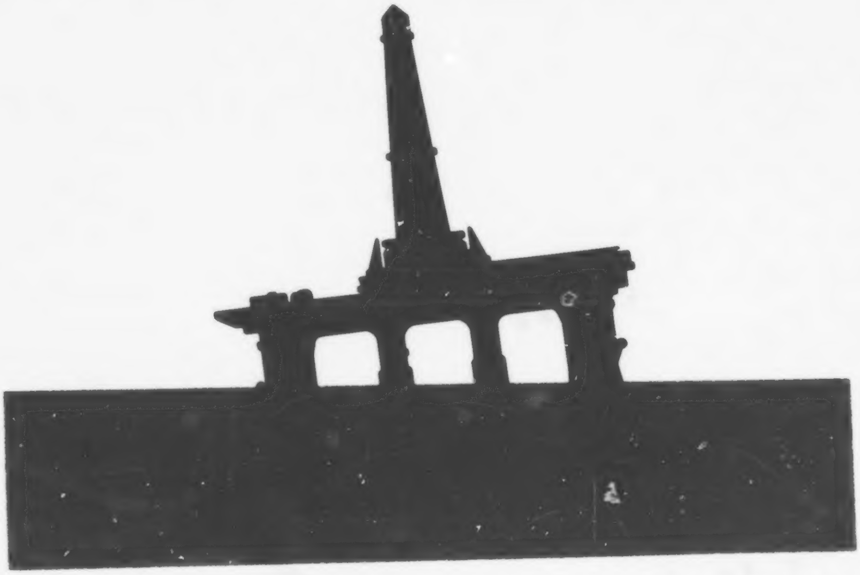
The industrial relations representative (safety engineer) reported to the Safety Division of ODECO in New Orleans and to the toolpusher on the rig. His prime responsibilities appear to have been training roustabouts on the job and monitoring industrial safety. He assisted in the conduct of the weekly fire and evacuation drills. His chief concern, however, was fire control; it appears that he had little, if any, responsibility for marine safety which presumably was the responsibility of the master.

THE FEBRUARY 6, 1982 INCIDENT

On February 6 the *Ocean Ranger* developed a sudden port heel of 6 degrees while taking on liquid cargo from a supply vessel. Bruce Porter, the ballast control operator on duty, testified that he began taking on fuel and drill water at 4:00 a.m. and was relieved by Captain Hauss at 6:00 a.m. so that he could complete a routine inspection tour.

Porter testified that Hauss had asked him to reset the manually controlled fuel tank valves in the pump room because the loading of fuel oil had stopped. Porter was in the process of completing this operation when the rig developed a list which was serious enough to result in the crew preparing to go to lifeboat stations. Senior ballast control operator Rathbun was called from his bunk to correct the list from the ballast control console. Rathbun later explained to Porter that Captain Hauss had been pumping out port tank 14 with the remotely controlled sea chest valve open. Porter could not explain why the sea chest valve was open, because the normal procedure while pumping out was to have it closed. The open sea chest valve caused rapid ingress of sea water ballast which the pumps could not counteract.

After the list had been rectified, Thompson, the toolpusher, in the presence of Jim Counts, ODECO's shore-based drilling superintendent, severely criticized Captain Hauss for causing the list and told him to be sure that it did not happen again. Captain Hauss agreed, according to Porter, not to operate the ballast control console again. Counts testified that both he and Thompson had lost confidence in Captain Hauss, but neither took any action to replace him immediately, a fact which reinforces the impression that the master was only on board in order to comply with U.S. Coast Guard regulations.



4.5 The *Ocean Ranger*, illustrated with a 6 degree stern trim, at the 80-foot draft, giving some indication of the severity of even relatively small trims.

This incident, which was not reported immediately to the Mobil office nor to the regulatory authorities, is worthy of note for several reasons. It illustrates the fact that, although the master was deemed to be responsible for rig safety and for the ballast control operators, he had not been trained in the operation of the ballast control system. It also establishes that on the night of February 14, the master on board the *Ocean Ranger* did not understand the ballast control system and the toolpusher was fully aware of this fact.

5

EVENTS BEFORE EVACUATION

CHAPTER FIVE EVENTS BEFORE EVACUATION

In February 1982 Mobil was operating, in addition to the *Ocean Ranger*, two other semisubmersible drilling units in its exploratory drilling program on the Grand Banks. They were the *SEDCO 706*, of United States registry and the *Zapata Ugland*, of Norwegian registry. The three semisubmersibles were moored approximately 170 miles[1] east of St. John's. The *Zapata Ugland* was positioned 19 miles north and the *SEDCO 706* was anchored 8 miles northeast of the *Ocean Ranger*.

On Friday, February 12, 1982, a weak disturbance in the Gulf of Mexico was identified by the Atlantic Weather Centre in Bedford, Nova Scotia. The disturbance moved off the coast of Georgia and developed as it progressed northward. By 8:30 p.m. on Saturday, the low had moved to about 210 miles south of Halifax. It intensified rapidly and moved toward the Avalon Peninsula of Newfoundland at a speed of about 35 knots. The low continued to move northeastward with little or no deepening and winds from the storm began to affect the area of the Hibernia Field at about 2:30 a.m. on Sunday. They continued from the southeast at 30 knots, and by 12:30 p.m. Sunday had increased to 50 knots, as the low moved to the northwest of the drill site (Appendix E, Item 4).

SATURDAY, FEBRUARY 13, 1982

On Saturday, February 13, the three rigs were engaged in drilling operations. The *Zapata Ugland* was preparing to pull its drill string to replace a worn drill bit. The *SEDCO 706* was attempting to retrieve a piece of equipment which had been lost in the hole, and the *Ocean Ranger* was drilling at Hibernia J-34.

A series of weather forecasts issued by NORDCO indicated weather conditions at the drill site would deteriorate during the early hours of Sunday, February 14, as a deep low centre approached the area (Appendix E, Item 2).

At 1:30 a.m. on Saturday, NORDCO forecast that wind speeds of 60 knots and maximum sea heights of 24 feet could be expected at the drill site by mid-afternoon on Sunday. At 7:30 p.m. on Saturday that forecast was changed to maximum wind speeds of 70 knots and maximum sea heights of 22 feet. The synopsis stated:

> A gale center . . . is forecast to develop into a storm center overnight and pass between St. John's and the drill areas about noon on Sunday . . . Gale force southeast winds expected to spread over the drill area around 14/06Z [2:30 a.m.] or shortly afterward then increase to storm force after dawn . . . A cold front tailing southward from the storm center will sweep across the area in the late afternoon with gale to storm force west to northwest winds, heavy seas, flurries and freezing spray anticipated by Sunday night.

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[1] In this chapter "miles" refer to nautical miles.

SUNDAY, FEBRUARY 14, 1982

NORDCO revised its weather forecast at 7:30 a.m. on Sunday predicting maximum wind speeds of 90 knots and maximum sea heights of 37 feet at 2:30 p.m. that day and stated in the synopsis:

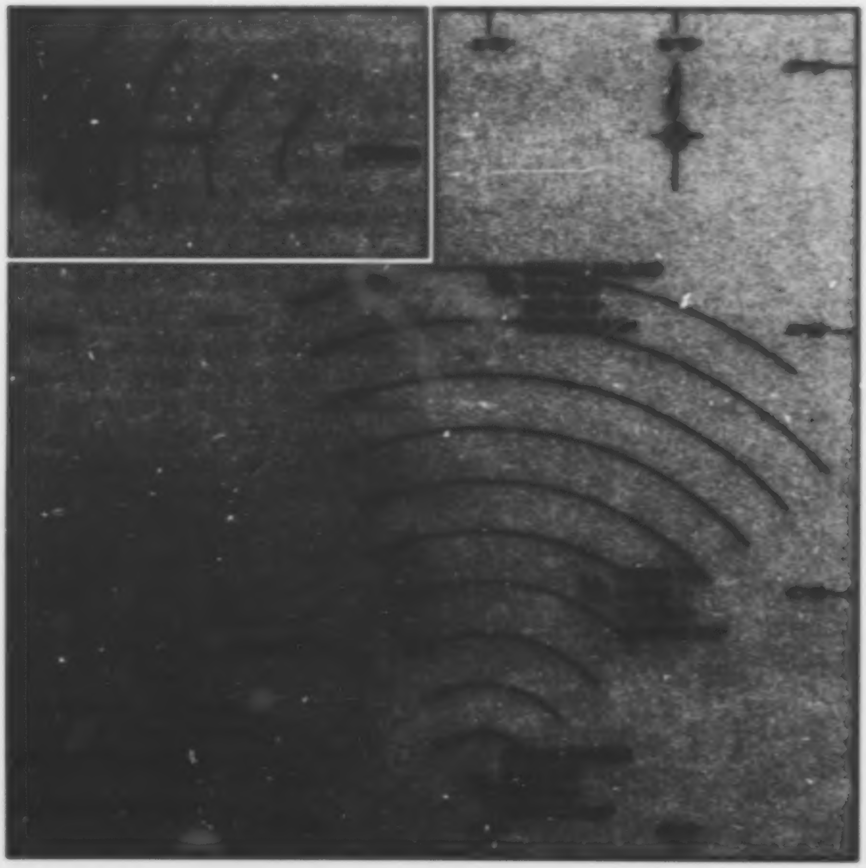
> The forecast trajectory of the low center has been amended to more northerly than the previous forecast but drastic deepening of the pressure center will create higher winds and waves earlier than expected in the previous forecast.

This forecast, as with all other forecasts issued by NORDCO, was forwarded to Mobil's shore base where it was telexed to each rig and to the shore-based office of each drilling contractor. This forecast was received by the *Ocean Ranger* at 8:00 a.m. Sunday.

1000 NST (1330Z)
The 0730 NST forecast is reviewed at Mobil office in St. John's.

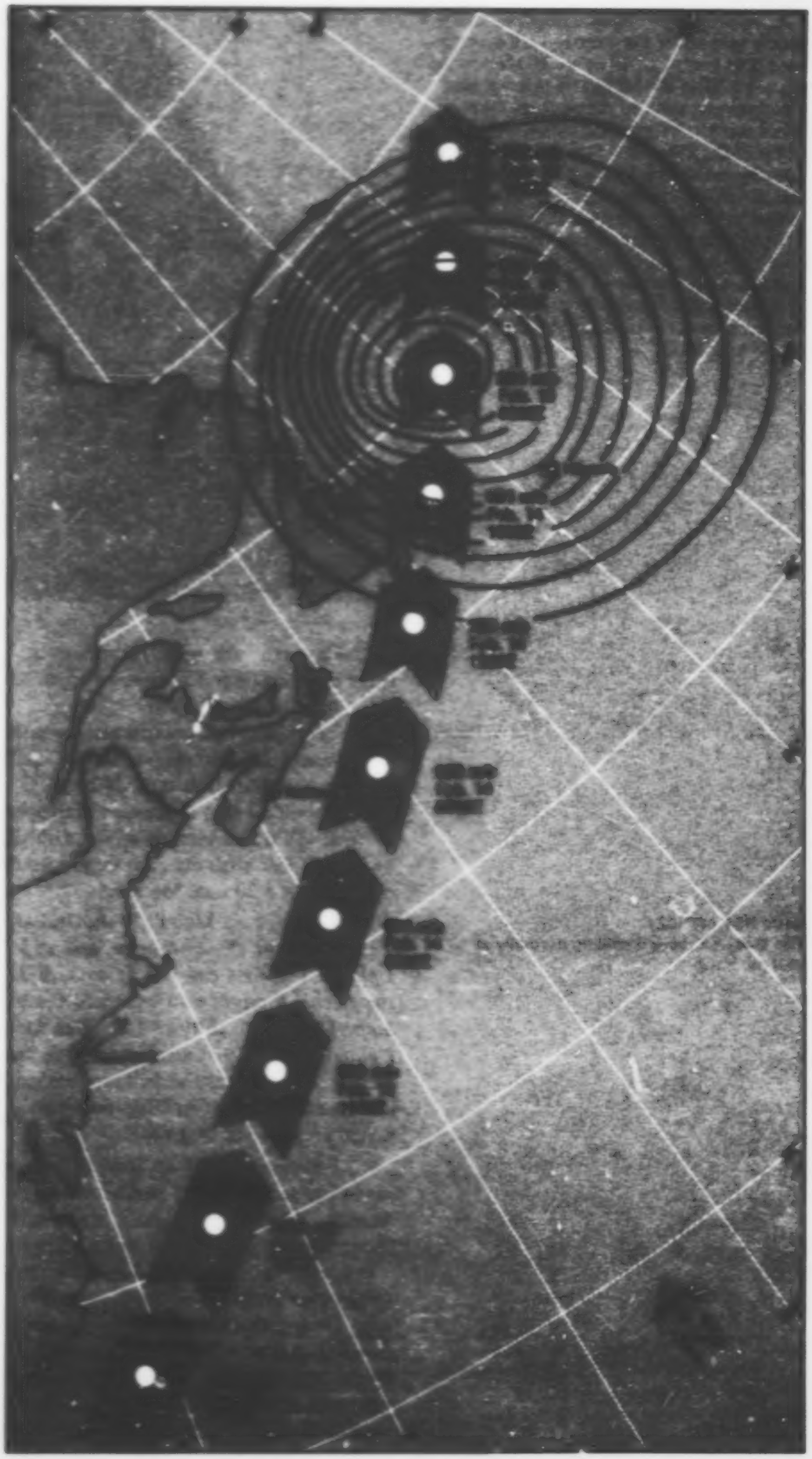
Mobil's area drilling superintendent in St. John's, Merv Graham, reviewed NORDCO's 7:30 a.m. forecast with Peter Kapral, a shore-based Mobil drilling foreman, at 10:00 a.m. on Sunday morning. Graham and Kapral were aware that a storm of short duration would pass over the rig sites. They wanted to ensure that the rigs would be in a position to cease operations and to implement procedures outlined in their contingency plans to assist them in riding out the storm. It was, according to Graham, Mobil's standard procedure to conduct a review whenever storms were forecast.

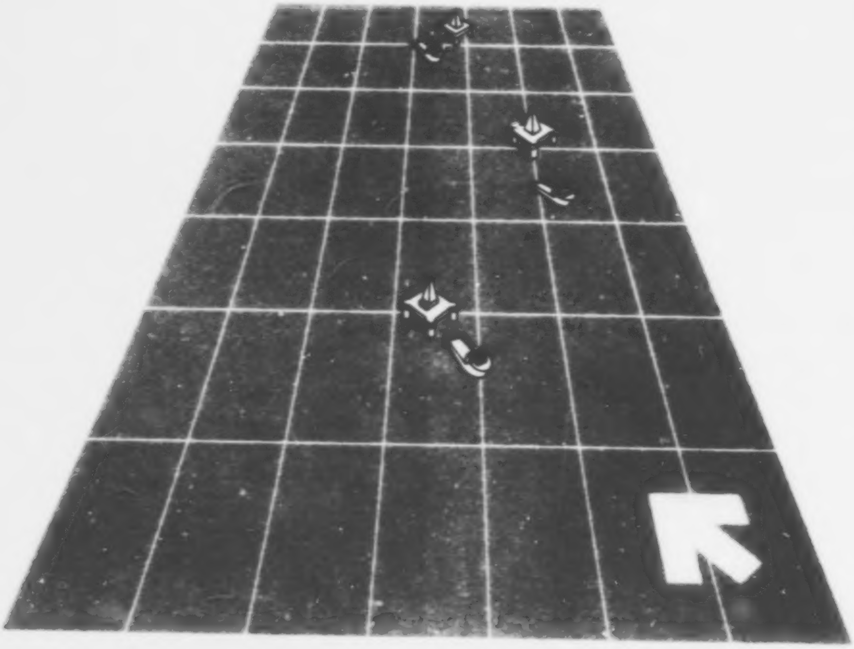
Early Sunday morning, ODECO's shore-based drilling superintendent, Jim Counts, went to his St. John's office to check the *Ocean Ranger's* morning report, which had been issued at 6:00 a.m., and to review the operations scheduled for that day with Kent Thompson, the toolpusher.



5.1 The location and orientation of the *Ocean Ranger*, the *SEDCO 706* and the *Zapata Ugland* on the Hibernia Field on February 14, 1982. The ranges are shown in nautical miles. A list of the names of the major participants, by their location during the sequence of events, is given at the end of the chapter.

5.2 The path of the severe winter storm that passed over the Hibernia Field on February 14-15, 1982.





5.3 Approximate standby positions of the supply vessels for the three rigs, relative to wind direction at 12:00 noon. The *Nordertor* (top), standing by the *Zapata Ugland*, was maintaining a standby distance of 1-4 miles. The *Boltentor* (centre) was within 3-6 miles of the *SEDCO 706*. The *Ocean Ranger's* standby vessel, the *Seaforth Highlander*, was within a 1-2 mile range. In order to maintain station in the 50-knot winds and 11-foot seas each vessel was proceeding slowly upwind, executing a 180 degree turn, and returning downwind.
This illustration is intended to show relative positions and orientations only, and is not drawn to scale.

Counts spoke with Thompson at 7:00 a.m. and again at 11:00 a.m. During these conversations Thompson advised Counts that drilling operations were proceeding normally. Shortly after 11:00 a.m. Counts left ODECO's offices and returned home because of the deteriorating weather in St. John's. He had advised Thompson that, should any problems arise, he could be contacted at his home on the MARISAT system. At 1:30 p.m. NORDCO issued its regular weather forecast update which predicted that maximum wind speeds of 90 knots and maximum sea heights of 35 feet would be observed at the drill sites at 8:30 p.m. that day. The forecast also predicted poor visibility and rough seas through the night with maximum sea heights of 46 feet at 8:30 a.m. Monday.

1400 NST (1730Z)
The *Ocean Ranger* is drilling normally at 18 feet per hour.

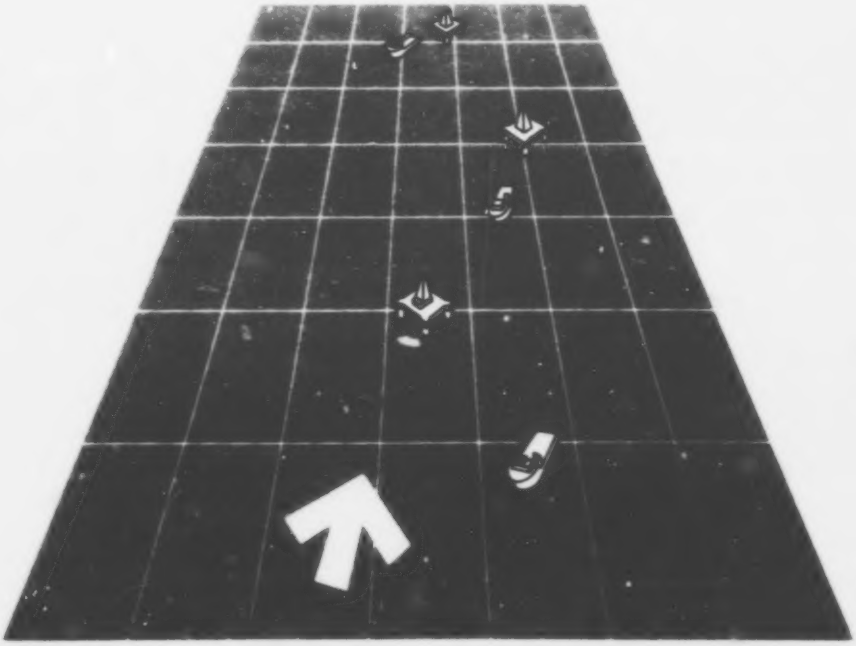
At 2:00 p.m. Mobil's Merv Graham, who was at his home at the time, received a call from the *Ocean Ranger*, and at 3:45 p.m. he received a call from the *Zapata Ugland*. The first call was from Jack Jacobsen, Mobil's senior drilling foreman on the *Ocean Ranger*, who informed Graham that the rig was drilling at 18 feet per hour. The second call was from Ken Lovell, Mobil's drilling foreman on the *Zapata Ugland*. He said that attempts to free the drill string were unsuccessful and that they were forced to shear the drill pipe and to disconnect the marine riser. This action was initiated because of drilling problems and not because of the weather conditions which prevailed at that time.

Following this 3:45 p.m. call, there were several important communications involving senior Mobil personnel on the *Ocean Ranger* (Jack Jacobsen and Bob Madden; Madden was also a Mobil drilling foreman on the *Ocean Ranger*) and on shore (Merv Graham and Peter Kapral). Graham testified that at 4:00 p.m., as he was preparing to leave his home for the Mobil office, he received a MARISAT call from either Jacobsen or Madden informing him that the storm had built up very rapidly, forcing the *Ocean Ranger* to discontinue drilling and to hang-off. He further testified that at 4:30 p.m. he arrived at the Mobil office and reviewed status reports on the three rigs. He was advised by Kapral that the three rigs had hung-off successfully and that the *Ocean Ranger* and the *Zapata Ugland* had been forced to shear their drill pipes. On the other hand, Kapral testified that at 4:42 p.m. he spoke with

Bob Madden and they discussed whether they should cease drilling and hang-off because of the deteriorating weather. Kapral further testified that at 5:30 p.m. Madden called to say that drilling had stopped and they were in the process of hanging-off. Madden also reported that high winds were blowing the motion compensator hoses out of the derrick and he was concerned that they might be severed. Under cross-examination, however, Kapral retracted this testimony and reaffirmed the account that he had given before the U.S. Coast Guard Marine Board of Inquiry. Before that Board, he had said that two calls occurred; at 4:30 p.m. he advised Madden to cease drilling; at 4:42 p.m. Madden reported that they had begun the process of hanging-off. Kapral then relayed this information to Graham who was at home, and at approximately 5:00 p.m. Graham arrived at Mobil's office.

Additional evidence regarding the time of hanging-off on the *Ocean Ranger* came from Merv Graham and Keith Senkoe, a Mobil drilling foreman on the *SEDCO 706*. Graham testified that at 6:47 p.m. he received a MARISAT call from Jacobsen advising him that the *Ocean Ranger* had hung-off. Senkoe testified that, shortly after 7:00 p.m., Jacobsen called and said that they were attempting to hang-off and were having difficulty with compensator hoses that had become entangled in the derrick. This conversation was overheard by Mobil drilling foreman, Rod Fraser, who confirmed Senkoe's evidence.

An examination of the records of telephone communications between the Ocean Ranger *and Mobil personnel on shore revealed that Graham's testimony on a 4:00 p.m. call from Jacobsen or Madden is in error. There is no record of this call on the MARISAT bills. A call at 4:52 p.m., lasting one minute, was made to Graham's home. Presumably he was not there and was either at Mobil's office or on his way there from his home. After considering all of the evidence, it is concluded that at 4:30 p.m. the* Ocean Ranger *was still drilling. The process of hanging-off was started shortly thereafter and was completed by 6:47 p.m., when Jacobsen called Graham at his home to advise that they were experiencing heaves of 20 feet and recurring sea spray in the drill floor area.*



5.4 At 6:00 p.m. the *Nordertor* and the *Boltentor* (top and centre) were maintaining approximately the same standby distances relative to their assigned rigs. With winds of 78-knots and seas of 29 feet, the *Seaforth Highlander* (bottom) continued to proceed with its bow to the prevailing wind and was almost 6 miles from the *Ocean Ranger*.

At 6:58 p.m. Thompson placed an eight-minute MARISAT phone call to Counts who was at his home, advising him that the *Ocean Ranger* had sheared off and disconnected. Thompson reported winds of 60-65 miles per hour and heaves of 22 feet. After speaking with Jacobsen at 6:47 p.m., Graham telephoned Steve Romansky, Mobil's east coast operations manager, around 7:00 p.m. and updated him on the status of the three rigs.

At approximately 7:00 p.m. the *SEDCO 706* was hit by a large wave, more severe than any other waves that evening. The force of the wave dislodged a small shed welded to the deck in the drill floor area, tore away several pieces of equipment which had been secured before the storm, and caused structural damage to a secondary longitudinal beam underneath the main deck. Given the draft of the *SEDCO 706*, the location of the damage on the main deck, and the fact that "green water" washed over the helideck, several witnesses estimated the height of this wave to be 70-80 feet. When the wave hit the *SEDCO 706*, the barge engineer was in the process of deballasting from an 80-foot draft to a 75-foot draft. This change of draft was completed at 7:25 p.m., and the *SEDCO 706* rode out the storm without incurring additional wave damage. The *Zapata Ugland* was also struck by one or more large waves which washed over the helideck around 7:00 p.m., but although the rig was jarred severely, it did not sustain any serious damage.

INTERNAL COMMUNICATIONS OVERHEARD

1900-2200 NST (2230-0130Z)
Internal VHF radio conversations on the *Ocean Ranger* are overheard on the *SEDCO 706* and the *Boltentor*.

Between 7:00 p.m. and 10:00 p.m., there was surprisingly little communication between the *Ocean Ranger* and the shore, in light of what was happening on the rig. Although Graham was contacted by Jacobsen on several occasions, there is no evidence of any communication between the toolpusher, Thompson and Counts, his superior on shore. Information on what transpired on the rig during these three hours is derived from a series of internal communications between personnel on the *Ocean Ranger*, which were overheard by persons on the *SEDCO 706* and on its standby vessel the *Boltentor*. The communications appear to have been made on hand-held VHF sets. They were overheard in the barge control room of the *SEDCO 706* by John Ursulak, Mobil drilling foreman; Fred Hatcher, watchstander[2]; and Don King, barge engineer[3]. On the *Boltentor* some of the conversations were overheard by Captain James Davison. The transmissions were at times poor, and other vessels in the area of the *Ocean Ranger* did not pick them up.

Evidence was received on the substance of these conversations, and in some cases, on the probable identity of the speakers. Ursulak, who had worked on the *Ocean Ranger*, was able to identify the voices of Thompson and Don Rathbun, the senior ballast control operator. Ursulak testified that he overheard Thompson inquire about the condition of the ballast control room and Rathbun respond that: ". . . the panel was wet, he was working on it and getting shocks off it . . . . [and that] . . . he had the cover off. . . ." About five minutes later, Ursulak overheard Thompson request an update and Rathbun replied:". . . that everything was fine and that they [were] picking up glass, mopping up water, tidying up." Don King and Fred Hatcher confirmed that reference was made to "cleaning up water and broken glass." Hatcher also stated that a voice he could not identify said that, ". . . all valves on the port side were opened by themselves."

Don King testified that in several of the conversations he recognized the voice of Domenic Dyke, the junior ballast control operator on the *Ocean Ranger*. King was able to identify Dyke because they had worked together on the *SEDCO 706*. He testified that he heard Dyke say that the P.A. system and gas detection system were not working. According to King, Dyke also said that "... they were getting shocks off other equipment ... [and that] ... a valve or valves were opening and closing on their own." King heard a second person (presumably the person to whom Dyke was communicating) state that "an electronics technician was on his way to the ballast control room."

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[2] On SEDCO rigs the term "watchstander" is used to identify personnel in charge of the rig's ballast system.

[3] At the time of the *Ocean Ranger* incident, the *SEDCO 706* did not have a qualified master mariner on board. The barge engineer was responsible for all marine operations at that time.

Captain Davison testified that he overheard a reference made to "broken glass and water", to which a person with what Davison identified as a southern United States accent replied: "...'well get some guys in here and get it cleaned up'...." Later, reference was made to "...'high powered cables in here'..." and "...'don't get anybody injured or killed or damaged'...." Davison also recalled that "someone said ... [that] ... there were valves operating, or closing, or opening ... or they were indicating that there were valves doing something, activating themselves one way or another."

The witnesses who overheard these conversations did not agree on the times when they took place. This is not surprising under the circumstances, since the witnesses were preoccupied with the safety of their own vessels and could not, at that time, have realized the significance of what they were overhearing.

Ursulak claimed that the two conversations which he overheard could have occurred as early as 7:30 p.m. or as late as 8:00 p.m. Similarly, Hatcher stated that according to his recollection the time of these conversations was between 7:30 p.m. and 8:00 p.m. King stated that the first conversation occurred after 8:00 p.m. He said that he was present in the barge control room while the *SEDCO 706* was being deballasted. The control room log indicates that the deballasting was completed at 7:25 p.m. King then completed a tour of the main deck to assess the wave damage, and returned from the main deck 20-25 minutes later. He then reported to the toolpusher and the Mobil drilling foreman on the damage and the steps taken to secure the deck cargo. On the assumption that it would take King five to ten minutes to make his reports and change clothes, the earliest he could have returned to the barge control room would have been 7:55 p.m. – 8:00 p.m. Although King could not be specific as to the time this conversation took place, he said that the period 8:00 p.m. to 9:00 p.m. would be most reasonable.

Captain James Davison of the *Boltentor* testified that during his 8:00 p.m. to midnight watch he overheard VHF traffic emanating from a rig that he could not, at that time, identify. He testified that about midwatch, 10:00 p.m., he overheard several VHF transmissions which were similar in content to those overheard on the *SEDCO 706*. Since the witnesses could not be more specific on the time of these VHF transmissions it is concluded that they started after 8:00 p.m. and continued periodically until 9:30 p.m.

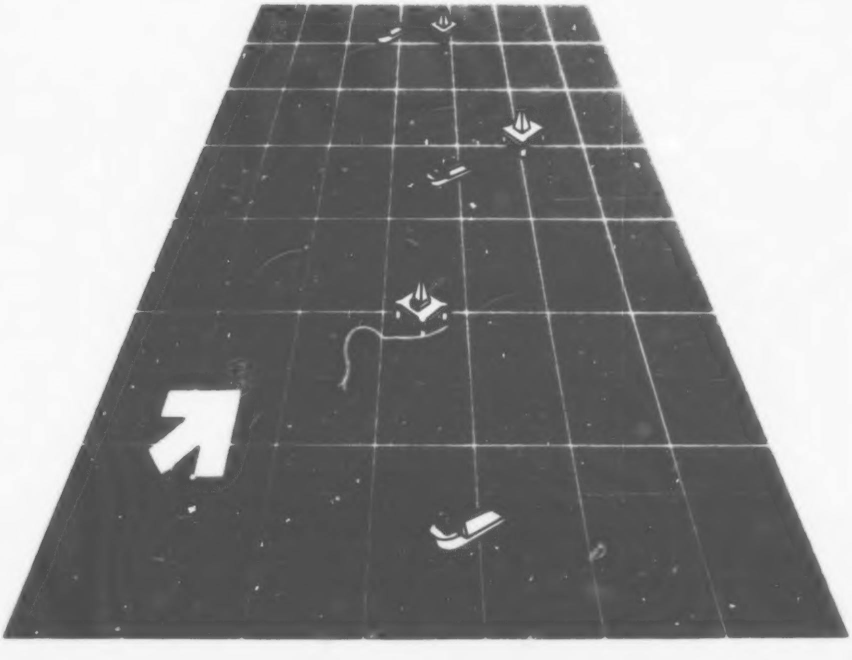
2044 NST (0014Z)
All equipment reported to be functioning normally.

At 8:44 p.m. there was a fourteen-minute MARISAT conversation between Jacobsen and Graham. Jacobsen reported 50-foot seas and winds of 90-100 knots. According to Graham, Jacobsen said that a portlight had been broken in the ballast control room but it was not causing any problems and all equipment was functioning normally.

There is conflicting evidence on the time of portlight failure. Merv Graham's handwritten and typewritten notes show that he was informed of the broken portlight in the 8:44 p.m. conversation with Jacobsen. However, he testified that he and Steve Romansky had discussed the portlight shortly after 7:00 p.m. He admitted that his testimony to that fact was based on a reminder from Romansky about the conversation and not on his memory or his notes. Romansky did not give evidence on this point but when interviewed shortly after the loss he was unable to pinpoint *whether the portlight was first discussed with Graham at 7:00 p.m. or at 10:30 p.m. Senkoe and Fraser testified that they recalled a mention of the broken portlight in a radio conversation between Jacobsen, Senkoe and Lovell at 7:00 p.m. However, neither witness was sure of his recollection as to time, and neither the* SEDCO 706 *radio log nor the* Zapata Ugland *radio log records any conversation with the* Ocean Ranger *at that time. Lovell recalled a three-way conversation at 9:06 p.m. in which the broken portlight was discussed. This was his first knowledge of the incident and he also believed that Senkoe had no knowledge of it until that time. On the basis of Graham's notes, the testimony of Lovell, interviews taken shortly after the loss, and the VHF conversations which commenced around 8:00 p.m., it is concluded that the portlight broke sometime around 8:00 p.m., February 14.*

At 9:00 p.m. the *Ocean Ranger* called the *Seaforth Highlander*, the supply vessel assigned to stand by the rig, to inquire how the vessel was weathering the storm. Captain Ronald Duncan, master of the *Seaforth Highlander*, replied that his vessel and crew were "not too comfortable" but "doing okay." The *Ocean Ranger* indicated it would check again later. This VHF transmission was overheard by a number of witnesses other than those present on the bridge of the *Seaforth Highlander*. Fred Hatcher of the *SEDCO 706* testified that during this transmission the *Ocean Ranger* inquired how far the *Seaforth Highlander* was from the *Ocean Ranger*, and was told that it was seven miles away. There is no evidence of any request, at that time, to have the *Seaforth Highlander* move closer to the *Ocean Ranger*.

At 9:06 p.m. Jacobsen called both Lovell of the *Zapata Ugland* and Senkoe of the *SEDCO 706*. Jacobsen indicated in this call that he had been asked by Graham to check with the other two rigs to determine how they were weathering the storm. Jacobsen told them that the *Ocean Ranger* had hung-off and disconnected, explaining that because of problems encountered with the motion compensator hoses, they had elected to shear the drill string rather than hang-off in the normal fashion. Jacobsen also told them that a portlight had been broken in the ballast control room, necessitating a clean-up which had been completed, and that there were no further problems arising from the incident.



5.5 At 9:00 p.m. the *Nordertor* and the *Boltentor* (top and centre) continued their dodging patterns. The *Seaforth Highlander* (bottom), proceeding into the 78-knot winds and 29-foot seas, had increased its distance from the *Ocean Ranger* to approximately 7 miles.

Don King of the *SEDCO 706* testified that sometime between 9:30 p.m. and 10:00 p.m., the final VHF transmission he overheard from the ballast control room of the *Ocean Ranger* indicated that "the electronics technician was there and everything was cleaned up and things were looking okay." In this, as in earlier transmissions he overheard, King recognized Dyke's voice, but not the voice of the other party. This was the last VHF transmission overheard emanating from the *Ocean Ranger's* ballast control room.

2200 NST (0130Z)
***Ocean Ranger's* ballast control system reported to be functioning normally.**

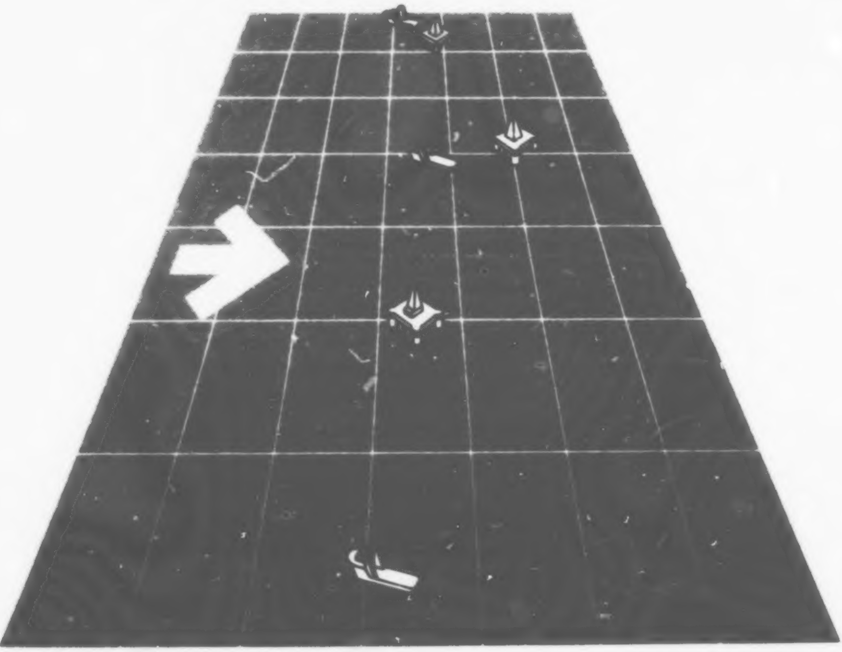
At 10:00 p.m. Jacobsen called Graham to report on the status of the three rigs. Graham testified that Jacobsen reported seas of up to 65 feet, that they were having no problems with the ballast control system, and that all equipment was functioning normally. Jacobsen and Graham agreed that the rigs were riding out the storm with no problems and Graham said that he would call each rig in the morning.

At 10:30 p.m. Graham called Romansky to report on the status of the rigs. He reported that a portlight on the *Ocean Ranger* had broken but that there were no problems and that all its ballast control equipment was functioning normally. At 11:30 p.m. Rick Flynn, Mobil's shore-based radio operator in St. John's, received the weather report from the *Ocean Ranger's* weather observer. The conversation was limited to the transmission of weather observations and there was no indication that the *Ocean Ranger* was experiencing any difficulty.

MONDAY, FEBRUARY 15, 1982

0100 NST (0330Z)
***Ocean Ranger* reports list to bow and requests assistance.**

There was no further communication between the *Ocean Ranger* and Mobil personnel on shore after 11:30 p.m. until Graham received a MARISAT telephone call from Jacobsen at 1:00 a.m., Monday, February 15. Jacobsen first attempted to contact Graham at his home by phone patch, but because of atmospheric interference was unable to do so. Flynn radioed the *Ocean Ranger* to inform Jacobsen that the phone patch could not be completed and he was advised that Jacobsen was speaking to Graham on the MARISAT. In this five-minute conversation Jacobsen asked Graham to notify the Coast Guard that the *Ocean Ranger* was "listing to the bow eight



5.6 At 1:00 a.m. the *Nordertor* and the *Boltentor* (top and centre) continued to maintain their previous dodging patterns. The *Seaforth Highlander* (bottom) had followed a course into the wind to a position approximately 8 miles from the *Ocean Ranger*.

to ten feet." Graham believed that Jacobsen's reference to listing should have been in degrees rather than feet, but he did not pursue that point with him. Jacobsen also told Graham that "they were attempting to isolate the problem." Graham asked Jacobsen how many people were on board the *Ocean Ranger* and Jacobsen replied that there were eighty-four. Graham advised Jacobsen that he would alert the Coast Guard and the helicopters under contract to Mobil, and also arrange to have the standby vessels of the other rigs proceed to render assistance. This, according to the evidence, was the first indication received by Mobil's shore-based personnel of serious problems developing on the *Ocean Ranger*.

0105 NST (0435Z)
***Ocean Ranger* is listing badly and calls *Seaforth Highlander* to come to close standby.**

The *Ocean Ranger* contacted the *Seaforth Highlander* at 1:05 a.m., and requested that it come to "close standby." A control room operator on the *SEDCO 706* overheard this VHF conversation and testified that the *Seaforth Highlander* asked what the problem was. The *Ocean Ranger's* radio operator, after an interval replied: "I am requested to tell you by the Mobil foreman that we are listing badly. . . ." The captain of the *Seaforth Highlander* testified that the *Ocean Ranger* indicated that "all counter measures [to regain trim] were ineffective." The *Seaforth Highlander* was located approximately eight miles south of the *Ocean Ranger* at this time.

At 1:06 a.m. Graham phoned the Search and Rescue Emergency Center (SAREC) in St. John's and advised them of the situation on the *Ocean Ranger*. At 1:09 a.m., a distress telex from the *Ocean Ranger* was received by a MARISAT operator in Connecticut.[4] The *Ocean Ranger* was connected with the U.S. Coast Guard Rescue Coordination Center (RCC) in New York and the following message was recorded:

> ARE EXPERIENCING A SEVERE LIST UNABLE TO CORRECT PROBLEM. NOTIFYING YOU PF PROBLEM PLEASE QSL. WE ARE THE ODECO OCEAN RANGER KRTB LOC 46.43.33N 48.50.13W AND ARE EXPERIENCING A SEVERE LIST OF ABOUT 10-15 DEGREES AND ARE IN THE MIDDLE OF SEVERE STORM AT THE TIME 12 DEGREES AND PREGRESSING..REQUEST ASST ASAP..WE ARE AN OFFSHORE DRILLING PLATFORM..WE WILL STBY AS LONG AS POSS WINDS AT THIS TIME ARE APPROX FROM THE WEST AT APPROX 75 KNOTS. RIG IS OF SEMI-SU SUBMERSIBLE BUILD AND IS LISTING SEVERELY 12-15 DEGREES TO THE PORT SIDE.. GENL INFO WE CHECK THAT ALL AVAILABLE WORKBOATS IN THE IMMEDIATE AREA ARE COMING TO OUR ASST THERE ARE TWO OTHER SEMI SUBMERSIBLES IN THE AREA AND WILL DO ALL POSSIBLE TO ASSIST

At approximately 1:10 a.m. the night radio operator on the *Ocean Ranger*, Ken Blackmore, contacted Mobil's shore-based radio operator Rick Flynn. He asked Flynn to transmit a Mayday for the *Ocean Ranger*. In the same transmission Jacobsen also spoke to Flynn and made the same request. He told Flynn that the *Ocean Ranger* was listing.

Jerry Higdon, second mate of the *Seaforth Highlander*, testified that at 1:10 a.m. he overheard the *Ocean Ranger's* call to the *SEDCO 706*, which indicated that the rig had a port list that could not be corrected, and that a Mayday relay would be required. The master of the *Seaforth Highlander* testified that the *SEDCO 706* issued a Mayday relay. He immediately increased his vessel's speed and proceeded under full power to the *Ocean Ranger*.

At approximately 1:11 a.m. Jacobsen called Keith Senkoe on the *SEDCO 706*. During the conversation he indicated that the *Ocean Ranger* "was not coming back for us" and that helicopters and supply boats would be required to assist in evacuation. At that time winds were gusting in the 70-80 knots range. This conversation was overheard in Mobil's St. John's office by Flynn, who was in telephone contact with SAREC.

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[4] In February 1982, MARISAT communications from the rig were routed through a ground station in Connecticut. The MARISAT operator would direct the MARISAT call to the receiving party using the telephone or telex. The distress telex is reproduced in full in Appendix G, Item 1.

There is a conflict in the evidence regarding the time the Ocean Ranger *issued its first Mayday. Baxter King, the SEDCO 706 radio operator recorded in his log that at 12:52 a.m. he picked up a Mayday from the* Ocean Ranger. *His actions and the evidence of other witnesses cast doubt on the accuracy of this log entry. King testified that he recorded a Mayday message that was sent out from the* Ocean Ranger *on the 2182 kHz International Distress Frequency at 12:52 a.m. He stated that almost immediately after picking up the Mayday, he received a radio call from Jacobsen on HF Channel 1. Jacobsen told him that the* Ocean Ranger *had a list which was progressing and asked him to send Mayday relays. He asked to speak with Senkoe. King testified that this call was his last communication from Jack Jacobsen and from the* Ocean Ranger. *If this is correct, then the evidence of Senkoe, who testified that at approximately 1:15 a.m. he spoke with Jacobsen about an emergency on the* Ocean Ranger, *must be incorrect. Similarly, the evidence of Don King, the barge engineer on the SEDCO 706, who testified that he overheard Senkoe's radio conversation with Jacobsen, portions of which were recorded by SAREC in St. John's and time logged at 1:14 a.m., must also be incorrect. It is inexplicable that Baxter King would record a Mayday from the* Ocean Ranger *at 12:52 a.m. and not notify his superiors of this event until 1:15 a.m. or thereabouts. It is concluded that the time in Baxter King's log is in error and that the first Mayday message issued by the Ocean Ranger was at 1:09 a.m., several minutes after Jacobsen advised Graham of the emergency situation on the rig.*

At 1:21 a.m. the *SEDCO 706* directed its standby vessel, the *Boltentor*, to proceed to the *Ocean Ranger* as a precautionary measure, and at 1:22 a.m. the *Zapata Ugland's* standby vessel, the *Nordertor*, was also directed to proceed to the *Ocean Ranger*. The *Nordertor's* position was given as being 20 miles from the *Ocean Ranger* and the *Boltentor* was 15 miles away.

0130 NST (0500Z)
The crew of the *Ocean Ranger* go to the lifeboat stations.

Ken Blackmore, the medic/radio operator on the *Ocean Ranger*, called Flynn at Mobil's shore base to say that the crew of the *Ocean Ranger* were going to lifeboat stations and requested that another Mayday relay be transmitted. Both the *SEDCO 706* and the Mobil shore base acknowledged the message. This was the last communication heard from the *Ocean Ranger*. The time was 1:30 a.m.

At 3:38 a.m. the *Nordertor* reported to the *SEDCO 706* that the *Ocean Ranger* had disappeared from radar.

Personnel Named in Chapter 5
Alphabetical

NAME	POSITION	COMPANY
BLACKMORE, Ken	Medic/Radio Operator, *Ocean Ranger*	ODECO
COUNTS, Jim	Drilling Superintendent, St. John's	ODECO
DAVISON, James	Master, *Boltentor*	Crosbie Offshore
DUNCAN, Ronald	Master, *Seaforth Highlander*	Seaforth Maritime
DYKE, Domenic (Nick)	Junior Ballast Control Operator, *Ocean Ranger*	ODECO
FLYNN, Richard	Radio Operator, Mobil Base, St. John's	Harvey Offshore Services
FRASER, Rod	Drilling Foreman, *SEDCO 706*	Mobil Oil
GRAHAM, Merv	Area Drilling Superintendent, St. John's	Mobil Oil
HATCHER, Fred	Watchstander, *SEDCO 706*	SEDCO
HIGDON, Jerry	Second Mate, *Seaforth Highlander*	Seaforth Maritime
JACOBSEN, Jack	Senior Drilling Foreman, *Ocean Ranger*	Mobil Oil
KAPRAL, Peter	Drilling Foreman, St. John's	Mobil Oil
KING, Baxter	Radio Operator, *SEDCO 706*	SEDCO
KING, Don	Barge Engineer, *SEDCO 706*	SEDCO
LOVELL, Ken	Drilling Foreman, *Zapata Ugland*	Mobil Oil
MADDEN, Bob	Drilling Foreman, *Ocean Ranger*	Mobil Oil
RATHBUN, Don	Senior Ballast Control Operator, *Ocean Ranger*	ODECO
ROMANSKY, Steve	East Coast Operations Manager, St. John's	Mobil Oil
SENKOE, Keith	Drilling Foreman, *SEDCO 706*	Mobil Oil
THOMPSON, Kent	Toolpusher, *Ocean Ranger*	ODECO
URSULAK, John	Drilling Foreman, *SEDCO 706*	Mobil Oil

Personnel Named in Chapter 5
By Location

ONSHORE	OFFSHORE	
St. John's	**Hibernia**	
	Ocean Ranger	*Seaforth Highlander*
GRAHAM, Merv	THOMPSON, Kent	DUNCAN, Ronald
KAPRAL, Peter	JACOBSEN, Jack	HIGDON, Jerry
COUNTS, Jim	MADDEN, Bob	
ROMANSKY, Steve	RATHBUN, Don	
FLYNN, Richard	DYKE, Nick	
	BLACKMORE, Ken	
	SEDCO 706	*Boltentor*
	SENKOE, Keith	DAVISON, James
	FRASER, Rod	
	URSULAK, John	
	HATCHER, Fred	
	KING, Don	
	KING, Baxter	
	Zapata Ugland	*Nordertor*
	LOVELL, Ken	________

6

TECHNICAL EVIDENCE

CHAPTER SIX TECHNICAL EVIDENCE

An extensive program of scientific investigation was undertaken into the structural, electrical and mechanical design of the *Ocean Ranger*. This program was carried out under the supervision of Dr. Ewan Corlett, Chief Technical Advisor to the Royal Commission. The results of this work provided the technical evidence on which the analysis of the cause of the loss has been based.

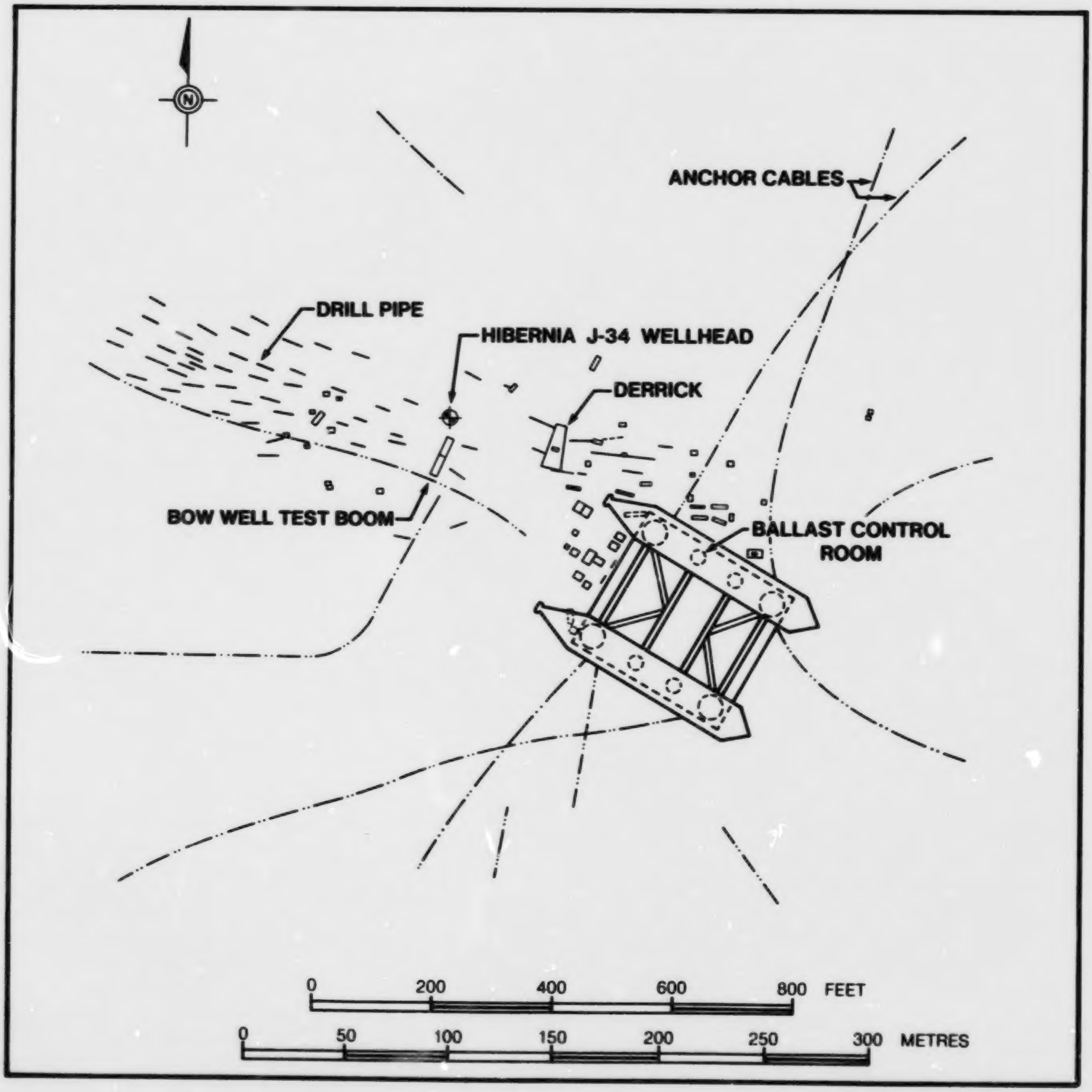
During July and August 1982, an underwater survey of the wreck and its site was carried out. The results of the diving program have provided important information on the condition of the rig and the circumstances contributing to the capsize. The Aviation Safety Engineering Facility (ASE) of Transport Canada carried out a technical examination of equipment recovered from the ballast control room and undertook a number of simulations to determine the cause and effects of the damage discovered. They identified features of the rig's electrical and mechanical systems that may have inhibited the crew's attempts to counter the problems leading to the loss.

It was apparent from the outset that an examination of the *Ocean Ranger's* stability and its behaviour in storm conditions would be necessary. Very little information was available regarding the rig's response to environmental forces and it was considered difficult, if not impossible, to develop adequate mathematical simulations to deal with the many factors involved. It was concluded, therefore, that a program of scale model testing supported by mathematical analyses would be the most effective method of assessing the effects of environmental forces, ballast transfers and downflooding on the rig's stability, as well as the behaviour of the rig at large trim angles. Analyses were also carried out on the ballast control panel and the pumping systems.

DIVING SURVEY

A series of sonar and underwater surveys conducted by Mobil Oil Canada Ltd., in February and March 1982, located the wreck in an inverted position, approximately 500 feet to the southeast of the Hibernia J-34 wellhead at a seabed depth of 255 feet. The superstructure was crushed into the seabed and the rig was resting on its upper deck. An examination was carried out using a remotely controlled vehicle (RCV) equipped with a closed-circuit television camera. The Mobil survey team located four areas of structural damage on the accessible portion of the wreck: significant damage to the bows and anchor bolsters of both pontoons; a damaged side girder and an area of collapsed under-deck plating at the base of the third starboard column; and two broken portlights in the ballast control room located in the same column. No structural damage was found at the critical nodes which connected the pontoons, columns, upper hull and transverse braces. An RCV examination of the wellhead and blowout preventer (BOP) revealed a considerable amount of debris near the wellhead, including a piece of drill pipe lodged against the BOP itself which, however, was essentially undamaged. The well was properly secured. (The J-34 well was subsequently re-entered and suspended during June 1982. The results of this program are detailed in Appendix F, Item 1.)

Planning for the Royal Commission's underwater survey took place during the early summer of 1982. A review of the "as-built" plans of the rig was carried out in


N
ANCHOR CABLES
DRILL PIPE
HIBERNIA J-34 WELLHEAD
DERRICK
BOW WELL TEST BOOM
BALLAST CONTROL ROOM
0 200 400 600 800 FEET
0 50 100 150 200 250 300 METRES

combination with a study of the video tapes and sonar recordings from the earlier Mobil survey. A diving support vessel, the ***Balder Baffin***, was engaged and equipped to act as the tender for the underwater operations. The purpose of the survey was to verify the information obtained by Mobil and to inspect the wreck for further indications of structural failure. In addition, a survey of the debris and of the mooring lines and soundings of the pontoon tanks were to be undertaken. Plans were made to enter the ballast control room, if possible, in order to retrieve documents and equipment relevant to the investigation.

The survey began in July 1982 with a thorough structural examination. A team of divers and an RCV survey confirmed the results of the Mobil survey. No additional damage was located. It was observed that the damage to the anchor bolsters and bows of both pontoons was similar, although the total area of damage was slightly greater on the bow of the port pontoon. It was concluded that the rig had hit the seabed while trimmed by the bow at a considerable angle and that the rig was also heeled to port at the time of impact. Both the port and starboard bow ballast tanks were punctured. The damaged longitudinal girder and the collapsed section of under-deck plating at the base of the third starboard column were re-examined during the survey. This area was identified as the forward outboard corner of the emergency generator room. On examination, the damage was concluded to be a consequence of, rather than a contributor to, the capsize of the rig.

It had been reported on the night of February 14 that one portlight in the ballast control room had failed; at the time of the survey two were found to be broken. It was also noted that the deadlights on all of the four portlights were closed. The divers removed from the ballast control room both damaged portholes and a third that was undamaged. These were later forwarded to ASE for detailed examination and testing.

The debris and mooring lines on the seafloor were surveyed for indications of the exact manner of the capsize. The pattern of drill pipe to the northwest of the wreck and the position of the derrick and equipment from the foredeck were considered to be consistent with the rig attaining a severe bow trim while positioned over the wellhead. Although the survey was not sufficiently extensive to determine the exact condition of the twelve mooring lines and anchors, it would appear that through some combination of anchor dragging and line breakage the rig had moved directly above where the wreck was found. The force of the impact on the seabed completely destroyed the drill floor, the accommodations area and all other structures above the upper deck. The anchor windlasses were dislodged from their foundations and were found scattered on the seabed.

The divers found that both the port and starboard manual sea chest valves, which were normally left open at all times, had been closed. They also carried out soundings of the pontoon tanks in an effort to determine the tank contents immediately before the capsize. The volume of air remaining in each tank was determined and then extrapolated to obtain the equivalent air volume at the surface. Several investigators have attempted to reconcile the results of the tank soundings with the tank contents noted in the February 14 stability report which was recovered by the divers from the ballast control room. All attempts have been inconclusive. It would appear that during the capsize and the subsequent sinking of the rig the contents of individual tanks underwent considerable change due to flooding through the vent lines, transfer of contents through open or leaking ballast valves and possible damage to the internal bulkheads between the tanks. The tank soundings were not considered to be sufficiently reliable to form the basis for conclusions regarding the loss of the rig.

The diving team entered the ballast control room and recovered documents which included a working copy of the stability report for February 14. The entire

6.1 The location of debris at the Hibernia J-34 site, as developed from sonar and underwater surveys. The anchor cables are only shown to the limit of the area surveyed.

6.2 This photomicrograph shows the distinctive lip of metal discovered around the entire circumference of the locking ring from porthole #4. The lip and the pattern of deformation at its base indicate that the portlight was broken in the inboard direction by high impact loading evenly distributed over the entire glass surface.

mimic panel from the ballast control console and the 64 solenoid valves from beneath the lower portion of the console were also recovered. Eighteen of the solenoid valves were found to have a brass bushing and a rod inserted in the valve housing. The equipment was retrieved in an essentially intact condition, although some minor damage occurred during salvage. The divers did not recover the fuse and relay panels from the ballast control console nor did they ascertain the position of the electrical circuit breaker and air supply valve (Appendix F, Item 2).

PORTHOLE EXAMINATION

The two damaged portholes were examined to determine the cause of the failure of the portlights. The one intact portlight was tested to determine the breaking strength of the glass (Appendix F, Item 3). Both damaged portholes were disassembled and the locking rings which held the portlights in the frame were inspected for signs of deformation that might indicate the forces involved in breaking the glass. The locking ring from porthole #4 exhibited a pronounced "lip" of metal on the edge of the ring that had been adjacent to the portlight; the locking ring from porthole #1 was undamaged. It was concluded from a subsequent metallurgical examination of the deformation that the portlight in porthole #4 had been broken by wave impact of short duration and great force. The lack of a similar deformation in the locking ring from porthole #1 indicated that the portlight had been subjected to a slowly increasing pressure over a longer period and that it had been broken by static water pressure and possibly debris impact during the sinking of the rig.

The portlight was manufactured in Japan to meet the Japanese Industrial Standard JIS-F2410 (1955) (Appendix F, Item 3). It proved after examination to be 0.3 millimetres thinner than the "as-built" drawings. The intact portlight was found to be extensively pitted, a condition which is known to occur with use and which reduces the strength of tempered glass. In comparison with equivalent samples of new portlights purchased in Canada and Japan, the *Ocean Ranger* portlight exhibited a more uneven pattern of internal stresses when viewed through polarized lighting techniques. This variation in stress within the glass, caused by uneven cooling during the tempering process, was not considered a contributing factor.

To determine the pressure required to break the recovered portlight, ASE carried out a testing program using air pressure to exert force on one side of the glass. It was tested to failure at a pressure of 68 pounds per square inch (psi). According to the applicable Japanese Industrial Standard, the portlight should have been able to withstand a constant pressure of 99 psi. The Canadian and Japanese glass samples were also tested; the Canadian samples failed at an average pressure of 105 psi and the Japanese samples at an average pressure of 97 psi. Intentional pitting of one sample reduced its breaking strength to 54 psi. The reduced thickness and the surface pitting combined to reduce the strength of the *Ocean Ranger's* portlight to 30% below the allowable minimum. Not only did the portlight fail to meet the specification for thickness shown on the "as-built" drawing and the industrial standard for strength, but even if the portlight had met both, the requirements were still insufficient to withstand the wave forces that, under predictable extreme storm conditions, could reasonably be expected at the level and location of the ballast control room portholes on the *Ocean Ranger*.

SOLENOID VALVE EXAMINATION

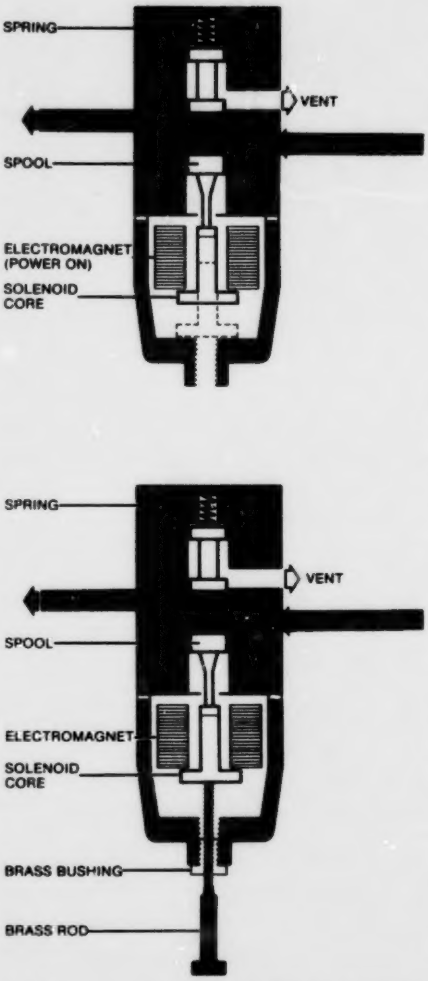
The 64 solenoid valves recovered from the ballast control room were forwarded to ASE for examination and testing (Appendix F, Item 3). They were arranged in six banks, each containing ten or eleven valves, and numbered sequentially with labels and small brass plates corresponding to the valve numbers on the mimic panel (P1-

P32, S1-S32). The solenoid valves worked as follows: when power to an electromagnet at the front of the housing was turned on, it pulled in the core which moved the spool, depressed the spring and opened the valve. When the power was turned off, the core and spool were returned to the closed position by the spring. In the open position, the solenoid valve directed compressed air to a ballast valve in the pump room, causing the valve to open. In the closed position, the compressed air was vented from the ballast valve and a spring caused it to close. The solenoid valve could also be opened manually by pushing in the core and plunger with a tool inserted through the threaded hole in the front of the valve housing.

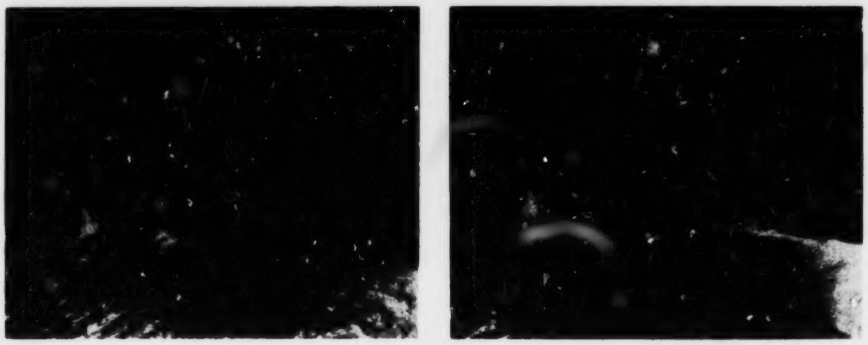
The divers found that 18 of the solenoid valves were fitted with a brass bushing and a brass rod. Many of the brass rods were bent or broken during salvage and four were inadvertently removed. Of the 64 valves received by ASE, 22 had rubber dust plugs inserted in the threaded hole of the valve housing and 24 were found to be empty. Measurements were made of the depth to which the brass rods were screwed in to determine whether the solenoid valves were opened or closed. It was found that all valves without the bushing or rod were closed. In contrast, all but one of the valves with the bushing or rod were open. The exception was valve P-13 which was half open, a condition which would probably have had the same effect as a fully opened valve.

After the brass rods and bushings were measured and removed, the solenoid housings were opened to allow examination of the interior of each valve. In each case, the solenoid core and plunger were found to be stuck in position because the lubricant inside the housing had congealed while the valves were in the sea. All of the valves functioned normally when cleaned and re-lubricated.

The solenoid cores were examined. In each of the 18 activated valves the core face was marked with a circular deposit of brass corresponding to the diameter of the brass rods. Of the other cores, 4 showed circular indentations and deformations but did not exhibit any brass residue, indicating that a non-brass tool had caused the markings. It is probable that these marks were made during the construction and testing of the rig and were unrelated to the loss. The remaining 42 cores were not marked in any way. It is concluded that all 18 solenoid valves found with bushings had been opened with rods and that the brass rods had not been used to activate any other valves.



6.3 The solenoid valves could be activated both electrically and manually; a circular pattern of brass residue was found on the core faces of the 18 manually-activated valves recovered from the wreck.



6.4 The 1:40 model of the *Ocean Ranger* in the testing basin at the Norwegian Hydrodynamic Laboratories, Trondheim, Norway.

MODEL TESTING

The program of scale model testing at the National Research Council, Ottawa (NRC), and the Norwegian Hydrodynamics Laboratory, Trondheim (NHL), involved a series of 182 individual tests carried out between November, 1982 and September, 1983 (Appendix F, Item 5). The 1:40 scale models used at both facilities were manufactured from the "as-built" plans of the rig, and included representations of the chain locker openings and sections of the ballast system in order to allow simulations of the effects of downflooding and of ballast transfers. Both model test basins were equipped to simulate the wind[1] and the wave forces determined from environmental data recorded on board the *Zapata Ugland* and the *SEDCO 706* on February 14 and 15, 1982.

One of the main purposes of the program was to determine the rig's susceptibility to downflooding and the potential effect of downflooding on its stability. Both models were constructed to allow downflooding into the forward columns through the chain locker openings which were designated by the American Bureau of Shipping as the "first point of downflooding". It is an ABS requirement that the angle at which downflooding would first occur be calculated during the design process, in order to comply with its rules. It had been determined that the angle of downflooding for the *Ocean Ranger*, at the 80-foot draft, was a 27 degree trim to the bow. At that angle of inclination sea water would enter the chain lockers. This calculation was based on a still-water condition, without regard to the fact that heavy seas can cause downflooding at a much smaller angle.

The tests showed that the rig was not susceptible to downflooding while it was substantially level at drafts as deep as 86 feet.[2] Downflooding only occurred at these drafts when the models were trimmed 10-12 degrees by the bow, or when the wave height was allowed to exceed the height recorded during the storm. These results established that the *Ocean Ranger* was capable of withstanding the storm conditions recorded at the site while level at the 80-foot drilling draft. During the tests at the 93-foot draft the models when level were subject to some flooding of the chain lockers but with bow trims in excess of 6 degrees rapid downflooding occurred.

An additional series of tests was performed based on the ballast distribution that was assumed to have existed on the evening of February 14. The tests examined the effects that would have occurred if the manually activated solenoid valves had actually been used to operate the valves in the ballast system. The models were subjected to wind and wave simulations in the test tanks, and the relevant valves were

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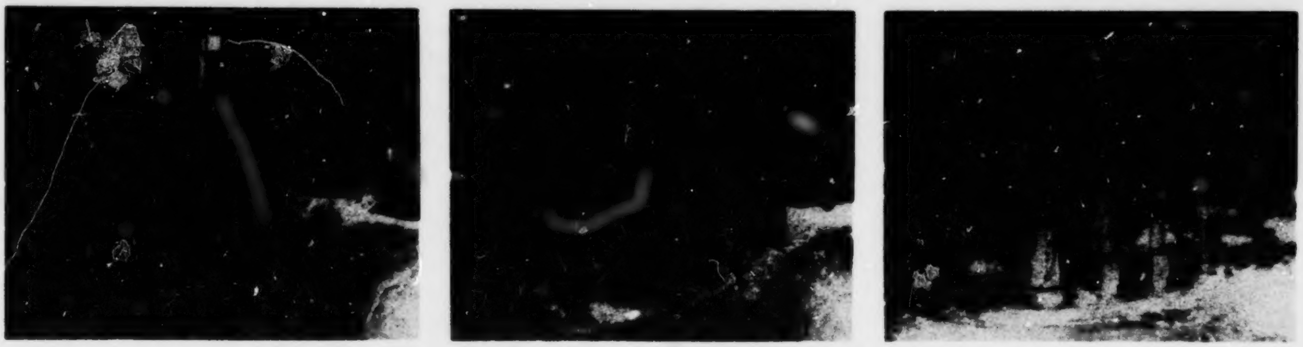
[1] Prior to the wave basin test, a 1:100 scale aerodynamic model was tested in the wind tunnel at the National Aeronautical Establishment of NRC in order to determine the rig's response to wind loads, and to develop data for the wind simulations used at NRC and NHL.

[2] A range of drafts from 72 feet to 93 feet were examined throughout the program, in order to allow for the possibilities that the rig had deballasted, or had increased its draft because of an unintentional ingress of ballast.



opened. In all cases the subsequent gravitational transfer of ballast, from the substantially full tanks at the stern to substantially empty tanks at the bow, resulted in bow trims in excess of 15 degrees and progressive downflooding into the chain lockers. Scaling difficulties in the models' ballast systems precluded an accurate assessment of the time required for full-scale gravitational transfer. The tests did, however, indicate the severity of unintentional ballast transfers and gave a realistic indication of the rig's motions and stability when trimmed by the bow.

One of the most difficult elements of the model testing program was the attempt to reproduce the capsize of the rig. The fact that the *Ocean Ranger*, with pontoons measuring 406 feet from bow to stern, had capsized in a water depth of only 255 feet created special problems in the model testing. In order to carry out a realistic simulation, the complex interaction between the ballast configuration, rig motions, environmental conditions, mooring system and flooding of the chain lockers and lower deck had to be considered; it was also necessary to make a number of assumptions in the absence of accurate knowledge of the condition of the rig before and during capsize. Furthermore, the models could not accurately reproduce the last phases of the capsize, because of the difficulties inherent in modelling the flooding of the lower deck space, the movement of the deck cargo and the ingress of water into the rig's void spaces. It was realized that, to simulate the capsize, considerable flooding of the lower deck and deckhouses, in addition to flooding of the chain lockers, would be necessary before the rig would reach the required degree of instability. It was apparent from the model tests that at significant bow trims the deck structure would be subjected to violent wave impact. The resulting damage to ventilators at the bow of the rig and to the superstructure in the accommodation area would have provided an unimpeded route for water to flood the sack storage area and, through the port bow stairwell, the accommodations areas of the lower deck.

Calculations of possible situations which would lead to capsize and analyses of the tests indicated that the probability of capsize diminished as the draft increased. The only model test that actually produced a capsize was performed at NRC, with a mean draft of 72 feet. Capsize at drafts in excess of 80 feet was considered to be unlikely, as the rig's trim in the final stage would be limited by the impact of the pontoon bows on the seabed.

A comparison of the model testing program results with the mathematical analysis produced for the U.S. Coast Guard by the David W. Taylor Naval Ship Research and Development Center revealed that the mathematical results made the rig appear less susceptible to downflooding in dynamic conditions. This simulation was affected by the limited ability of the computer program to model wave conditions in a realistic manner and by the many arbitrary assumptions that were necessary in setting up the program.

A number of studies were undertaken to verify the stability information contained in the ***Ocean Ranger Booklet of Operating Conditions***. This information formed the basis for the day-to-day operational decisions affecting the stability of the rig and its accuracy was critical for safe operation. The ODECO stability data were found to be complete and generally accurate. Consideration was also given to the effects of the mooring system on stability and to the potential effect of "lightship growth"[3] on the rig. It was determined, however, that these factors did not play a role in the loss.

BALLAST SYSTEM STUDIES

From the outset it was suspected that the cause of the disaster was directly connected with a loss of control over the ballast system. The severe port bow list reported before the abandonment of the rig and the inability of the crew to restore it to level condition both indicate that a serious problem had occurred in this system. The results of the ASE solenoid valve examination served to strengthen this suspicion. An investigation was also undertaken by ASE of the electrical and mechanical components of the ballast control system (Appendix F, Item 3).

The port and starboard sections of the mimic panel were found to be essentially intact when recovered, although valve control switches P-2 and P-8, indicator S-35, and the lampholder from switch P-17 were missing and presumed to have been lost during the salvage effort. Four of the twelve green ("run") pump switch lenses and ten of the twelve red ("stop") pump switch lenses were also missing from the panel; the video tapes taken inside the ballast control room of the wreck showed that these lenses were missing before the recovery operation began. All of the valve control switches were found to have their original soldered connections. Apparently, no attempt had been made to open or replace them.

The mimic panel components were examined visually for any signs of damage that may have resulted from an electrical malfunction. Only one component, valve control switch P-19, was found to be damaged; the lower portion of its housing showed evidence of arcing and burning. This was consistent with short-circuiting of the 115-volt terminals at the base of the switch from an accumulation of sea water.

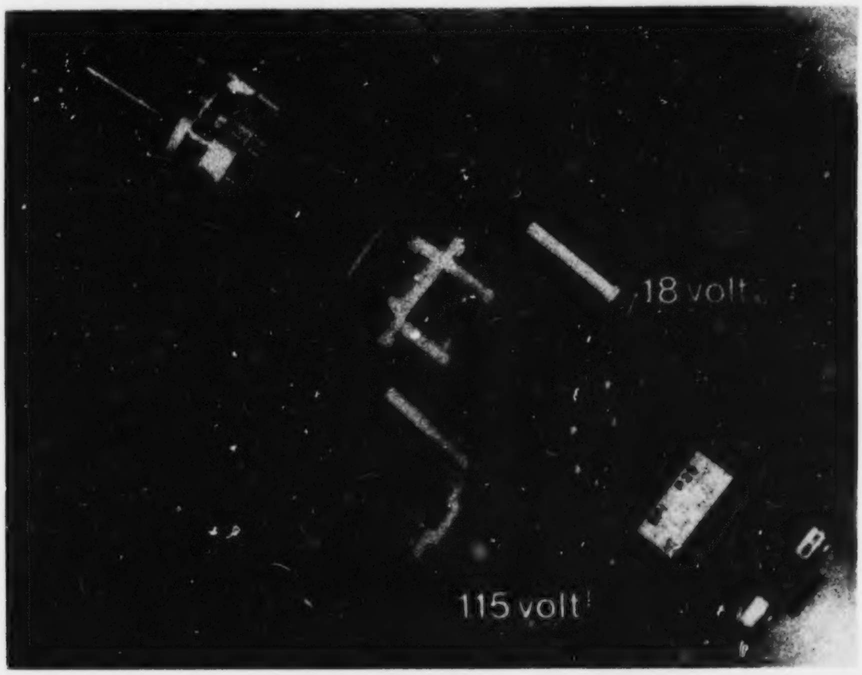
The second phase of the panel inspection was an optical and scanning electron microscope examination of all the indicator light bulbs. It was determined that of the 184 bulbs[4] recovered, 80 bulbs, or 43% of the total, were not functional because of broken filaments. Seventy-six of these showed evidence of failure due to exposure to excessive voltage. The failed bulbs were randomly distributed over the entire panel. All of the bulbs were found to be aged, indicating that none had been replaced during the night of the loss.

In assessing the damage to switch P-19 and the valve position indicator lights, the investigators noted that the 24-volt indicator circuit terminals and the 115-volt control circuit terminals were located close together at the base of the switch housing. They concluded that sea water entering switch P-19 had created a conductive bridge between the 24-volt and the 115-volt circuits[5], causing many of the indicator lights in the 24-volt circuit to fail because of overvoltage. The distribution of undamaged bulbs indicated that sea water had entered a large number of valve control switches, causing in some cases short circuits, *preventing* current from passing through the bulb filaments and consequently protecting them from damage. The result was a random distribution of damaged and undamaged bulbs.

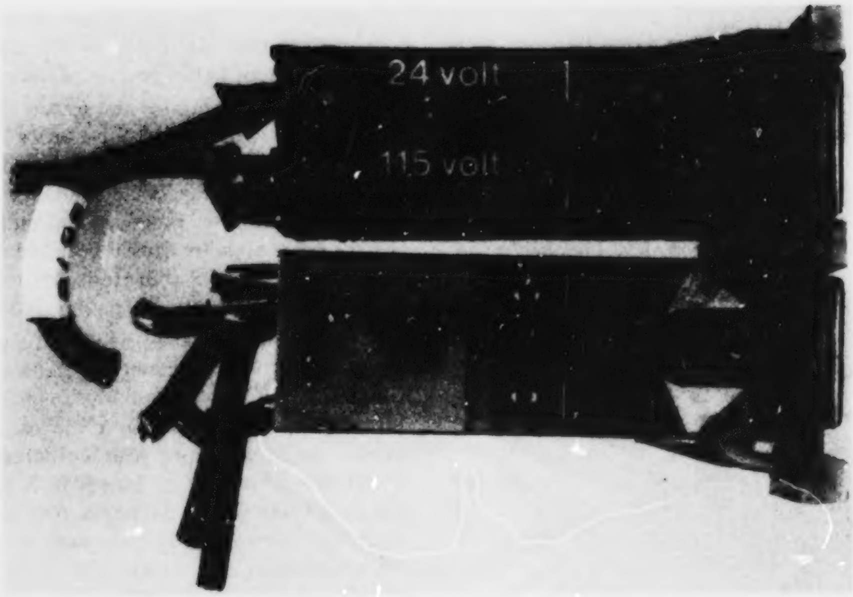
[3] "Lightship growth" is an unrecorded change in the weight of a vessel because of the gradual accumulation of paint, and other material. A vessel of the *Ocean Ranger's* size might be expected to have an annual lightship growth of up to 20 tons.

[4] The mimic panel included 168 valve position indicator bulbs and 24 pump switch bulbs. Eight valve indicator bulbs were lost during salvage.

[5] This effect may have occurred at more than one site in the mimic panel, although switch P-19 is considered to be the most likely location.

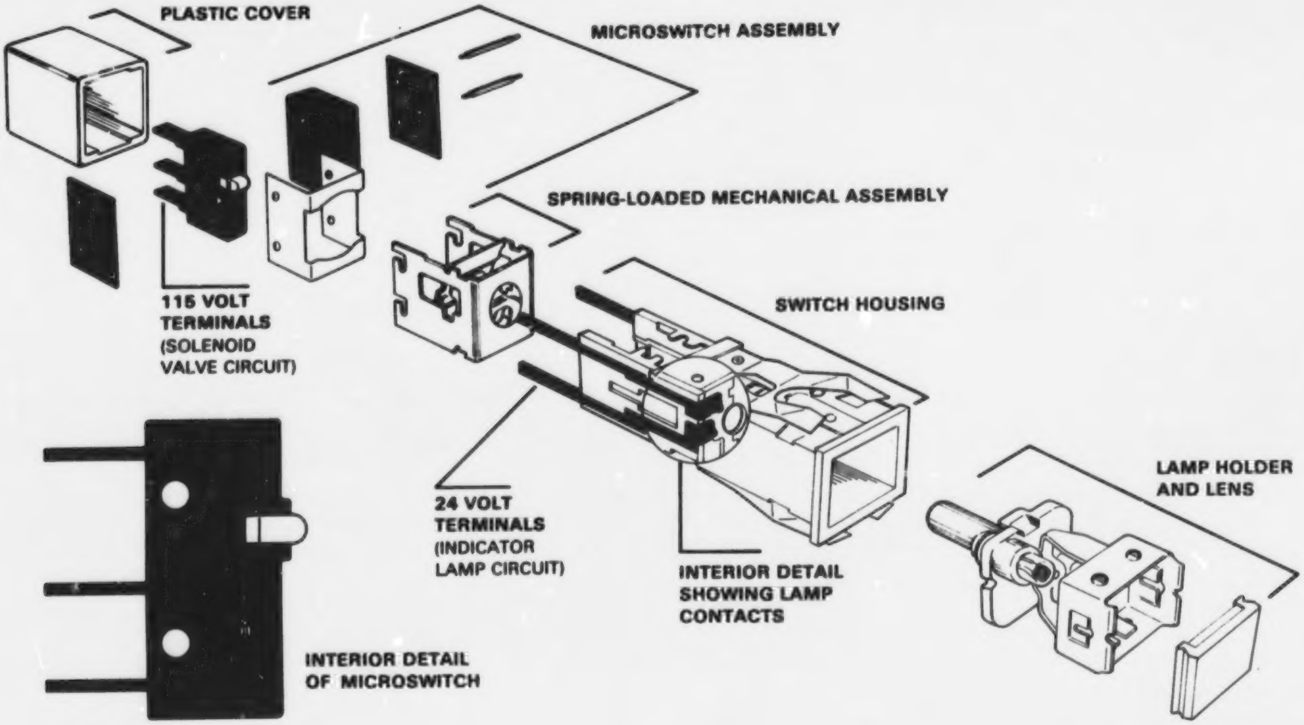


6.5 A disassembled pump switch identical to those used in the mimic panel. The failure of some of the indicator lamps in these switches was caused by sea water entering the transformer housing near the base of the switch, and short-circuiting the primary 115-volt and secondary 18-volt terminals.



6.6 Valve control switch P-19 was the only mimic panel component which was visibly damaged. The melted area near the base of the housing was caused by a short circuit between the 24-volt and 115-volt terminals.

The failure of the pump switch indicator lights, which were connected to a separate 115-volt circuit through a 115-volt/18-volt transformer in the body of each pump switch, was attributed to short circuiting of these transformer terminals. Each pump switch was equipped with a rubber gasket that prevented sea water on the surface of the mimic panel from entering the switch housing. Tests showed, however, that water could seep from the surface of the mimic panel through the valve switch


PLASTIC COVER
MICROSWITCH ASSEMBLY
SPRING-LOADED MECHANICAL ASSEMBLY
115 VOLT TERMINALS (SOLENOID VALVE CIRCUIT)
SWITCH HOUSING
24 VOLT TERMINALS (INDICATOR LAMP CIRCUIT)
LAMP HOLDER AND LENS
INTERIOR DETAIL SHOWING LAMP CONTACTS
INTERIOR DETAIL OF MICROSWITCH

6.7 This illustration shows the components of the valve control switch used in the mimic panel. Short circuiting was found to occur: between the lamp contacts; between the leads connecting the lamp contacts to the base of the switch; between the 24-volt and the 115-volt terminals at the base of the switch; and within the microswitch itself.

openings and enter the pump switch housings, short-circuiting the transformers and causing the bulbs to fail because of excessive voltage.

In order to examine the effects of sea water on the electrical system of the mimic panel, ASE carried out a series of tests using identical new components purchased from the original equipment manufacturers in Japan. These tests demonstrated that sea water could readily enter the valve control switches. Even small amounts of sea water produced a dimming and flickering of the indicator lights and in some cases actually caused both the green and red lights to be illuminated simultaneously. In many of these tests, sea water was found to cause a short circuit capable of energizing the attached relay and solenoid valve.

A simulator of the original mimic panel was also tested in order to gauge the possible electrical effects of sea water on the panel. Sea water was poured over the simulator, but no attempt was made to duplicate the amount or velocity of the ingress of water on the night of the loss. The initial effect of the flooding was to short circuit the 24-volt valve position indicator circuit and cause the fuse to fail. It was discovered later that a 5-amp fuse had inadvertently been used instead of the required 10-amp fuse. Attempts to restore the circuit during the course of the test by inserting a new 10-amp fuse were unsuccessful, indicating that the short circuits were continuing even as water drained from the panel. During the first ten minutes of the test, 10 of the 32 valve control switches exhibited short circuits which activated the associated relays in the simulator. In the *Ocean Ranger's* system this would have caused the solenoid valves beneath the console to open and that in turn would have opened the remotely operated ballast valves in the pump rooms if the compressed air supply to the console was on. A subsequent examination of the affected switches in the test panel showed salt deposits inside the associated microswitches, confirming that sea water had entered the microswitches and caused an internal short circuit.

As the test progressed, many of the indicator lamps (both "open" and "close") were observed to flicker and light very brightly in a random pattern across the panel. This effect was accompanied by sparking in the interior of the panel. There was no 24-volt power source to the indicator light circuit at this time because of the earlier fuse failure. It was therefore concluded that the 115-volt and 24-volt circuits had become interconnected by sea water. An examination of the indicator light bulbs revealed that many had failed because of excessive voltage in a manner similar to those recovered from the wreck and that a number of switches exhibited damage similar to that of the recovered switch P-19. The extent of damage in the simulated panel was greater than that found in the recovered mimic panel. This was probably due to the fact that the power was left on for over an hour during the test, whereas on board the *Ocean Ranger* the power to the ballast control console was probably turned off shortly after the portlight failure.

The design and operational aspects of the *Ocean Ranger's* ballast control system were analysed in the technical investigation. One of the factors affecting the proper operation of this system was the signals provided to the operator regarding the status of the equipment through the ballast control console and its associated instrumentation. The mimic panel was designed to provide a means of allowing the operator to open/close valves and operate pumps (control) and to determine the current valve and pump status (monitor). The control and monitoring functions were not separated as is normally done so that each system operates independently. The *Ocean Ranger* system was designed with the valve control and monitoring systems interconnected through relays in the console[6]; while this arrangement operated properly under normal conditions, it created an unnecessary limitation of the information available to the operator and made both systems susceptible to common faults. The consequences of this design flaw will be examined in the next chapter.

The investigation of the ballast pumping system also revealed a number of limitations. The major limiting factor in the design of this system was the location of the pump rooms at the stern of the vessel. This factor made deballasting increasingly difficult as the rig assumed a trim by the bow because of the increasing vertical distance between the suction inlet in the ballast tank and the suction inlet at the pump (Appendix F, Item 4).

Conversely, trimming the rig to the stern would actually improve the performance of the system. Testimony indicates that the ballast control operators were not only aware of this effect, but were also accustomed to using a slight stern trim to aid in pumping out forward tanks. It is also evident that a port or starboard heel would not have an appreciable effect on the operation of the system.

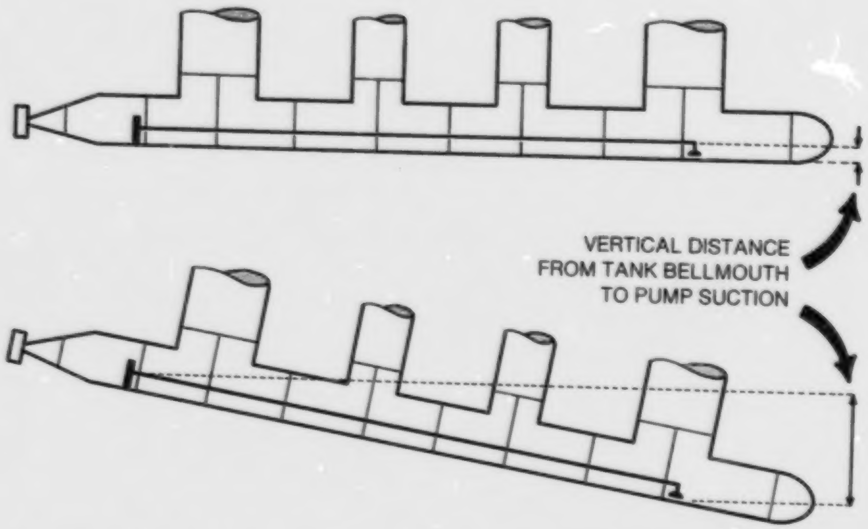
Another limiting factor in the ballast pumping system resulted directly from its mechanical design. It violated the standard engineering practice of balancing the size of the pumps, the diameter and length of the suction lines and several other factors in order to guarantee reliable performance over the operating range[7] of the system. The use of very powerful, high capacity pumps combined with the relatively small diameter suction lines connecting the pumps to the ballast tanks severely restricted the operating range over which the ballast system could successfully function. Some method of "throttling" or reducing the flow through the ballast pumps would have greatly improved the efficiency of the system.[8] Although the requirement for a throttling mechanism was noted on the construction plans, it was never installed. Larger

[6] Current classification society rules do not allow this type of arrangement.

[7] In this context, the term "operating range" refers to the level of tank contents and the attitude of the rig which could reasonably be expected under normal or emergency conditions.

[8] Operation of the system could also have been improved by pumping from more than one ballast tank simultaneously, but this was not generally recognized by the ballast control operators who normally pumped from only one tank at a time.

6.8 As the rig trimmed to the bow the vertical distance between the suction inlet in the tank and the suction inlet at the pump increased, reducing the ability of the system to pump out the forward tanks.



diameter suction lines in the system would also have helped. ODECO has indicated that this consideration is included in all of their current designs.

The effect of these design weaknesses on the rig's ballast system would have seriously hampered any attempts to right the rig from the severe trim reported on the night of the loss. The rate at which ballast could be pumped from the bow tanks would be reduced to zero as the trim progressed. In normal operations, the rate of flow from a given tank is unimportant; under the circumstances which existed on the night of the loss, the flow rate from the bow tanks was a critical factor.

7

LOSS OF THE RIG

CHAPTER SEVEN LOSS OF THE RIG

In the course of its investigation the Royal Commission has gathered a great deal of technical evidence, inspected the ballast control room and pontoons of the sunken rig, and conducted a series of model tests designed to elicit information concerning the probable behaviour of the *Ocean Ranger* in various wind, sea, and loading conditions. It was recognized however that technical evidence alone would not explain the cause of the loss and, accordingly, many witnesses were called to provide information on the customary operating procedures aboard the *Ocean Ranger* and on the established patterns of behaviour of those in key positions. This evidence, combined with the technical data available, provided the basis on which conclusions were reached concerning the cause of the loss.

It was earlier concluded that the *Ocean Ranger* was still drilling at 4:30 p.m. on the afternoon of February 14, 1982, and that the hang-off and disconnect process was started shortly after that time and completed not later than 6:47 p.m. Testimony indicated that accepted practice on the Hibernia Field is to deballast a rig five feet or more following disconnect in order both to increase the air gap[1] and to reduce the likelihood of the marine riser damaging the blowout preventer on the seafloor. Testimony, however, also indicated that the *Ocean Ranger* had never followed this deballasting practice and had, in fact, demonstrated a capability to continue drilling in weather conditions too severe to permit other rigs to do so. Indeed the *Ocean Ranger* had disconnected due to weather conditions only once during its five-year operating history, on January 16, 1982. On that date, the maximum reported heave was 22 feet, maximum reported seas were 49 feet and maximum swell 25 feet. The maximum reported pitch and roll were 4.5 degrees and 5.5 degrees respectively. The *Ocean Ranger*, however, did not deballast but maintained its 80-foot draft throughout. Evidence indicated that the weather conditions and rig motions were not dissimilar on February 14.

Witnesses testified that, if more clearance between the marine riser and the blowout preventer were required after disconnecting to prevent damage to this equipment, the alternatives considered before deballasting would be to lift the riser with either the travelling block or the motion compensator. Although there were reported problems with the compensator hoses on February 14, the riser could have been raised by means of the travelling block. As the *Ocean Ranger* had never previously deballasted because of storm conditions and in the absence of any report that it did so then, it is concluded that the rig had not deballasted from its 80-foot draft before portlight #4 broke in the ballast control room.

[1] Air gap refers to the distance between mean sea level and the underside of the lower deck of the rig.

7.1 One of the three portholes removed from the wreck. The deadlight was closed and dogged.

PORTLIGHT BREAKAGE

There is no doubt that the breaking of this portlight, sometime between 7:45 and 8:00 p.m., was the first link in the chain of events leading to the loss of the *Ocean Ranger*. Evidence indicated that the thickness of the glass, as specified on the plans furnished by the supplier of the portlight, was insufficient to withstand the wave forces under predictable extreme storm conditions and, moreover, that as the glass aged, pitting of its surface by water-borne or air-borne particles would diminish its strength. In addition, the installed glass failed to meet even the standard of thickness specified on the plans.

The size of the lip on the locking ring of portlight #4, which broke before the capsize, was approximately twice the size of the lip on portlight #2, which was recovered intact, after the latter was tested to glass failure at 68 psi. Testimony was given that the pressure necessary to produce a lip of the magnitude found on portlight #4 would be at least twice that amount. It was suggested by counsel for ODECO that the force of a wave alone was unlikely to approach that pressure and argued that the portlight was broken by heavy wave-borne debris. He argued that since the debris would necessarily be carried at or near the water surface, the portlight would not be subject to a large head of water and therefore, little water would enter the control room. The technical examination of the portholes recovered does not support this argument. Research on shock pressures generated by breaking waves indicates that dynamic pressures in excess of 140 psi are possible for short durations.[2] Examination of the recovered portlight confirmed that the glass was broken by the application of uniform pressure over its entire surface and not by debris impact.

Each porthole, as designed and installed, included on the inside a metal deadlight which could be lowered and secured over the glass when it was anticipated that waves might break on the portlight, but there were no instructions for the use of these deadlights and no standing orders that they be closed during storm conditions. Testimony indicated that appropriate instructions have now been included where relevant in all ODECO manuals. Notwithstanding the absence of instructions, if the crew, acting in accordance with good seamanship and common sense, had closed the deadlights in the ballast control room before 7:45 p.m. on February 14 the first link in the chain of events would not have been forged and the loss of the *Ocean Ranger* and its crew would have been prevented. It must be recognized, nevertheless, that if full consideration had been given in the design of the rig to the severe environmental conditions under which the rig might be operating, several other links in the chain of events which led to the capsize would not have been forged. For if the control console had been waterproof; or if it had been protected from any sea water that might come in through a broken portlight; or if the portlights themselves had been impregnable to the force of waves under predictable environmental conditions; or if the ballast control room had been located at a higher level on the upper deck and a system more sophisticated than draft marks attached to the columns had been provided for checking the draft, then, again, there would have been no chain of events and no loss.

Extensive evidence was presented with respect to the quantity of water that entered the ballast control room after the portlight was broken. The estimates ranged from half a ton to over 20 tons on the basis of various assumptions that may or may not be valid. Such unknown factors as the size, steepness and velocity of the wave, the attitude of the rig at the time of impact and the time taken to close the deadlight combine to allow considerable latitude in these estimates. But whatever the amount of water that entered the ballast control room, it was sufficient to wet the panel across its entire surface and thus initiate the sequence of events that followed.

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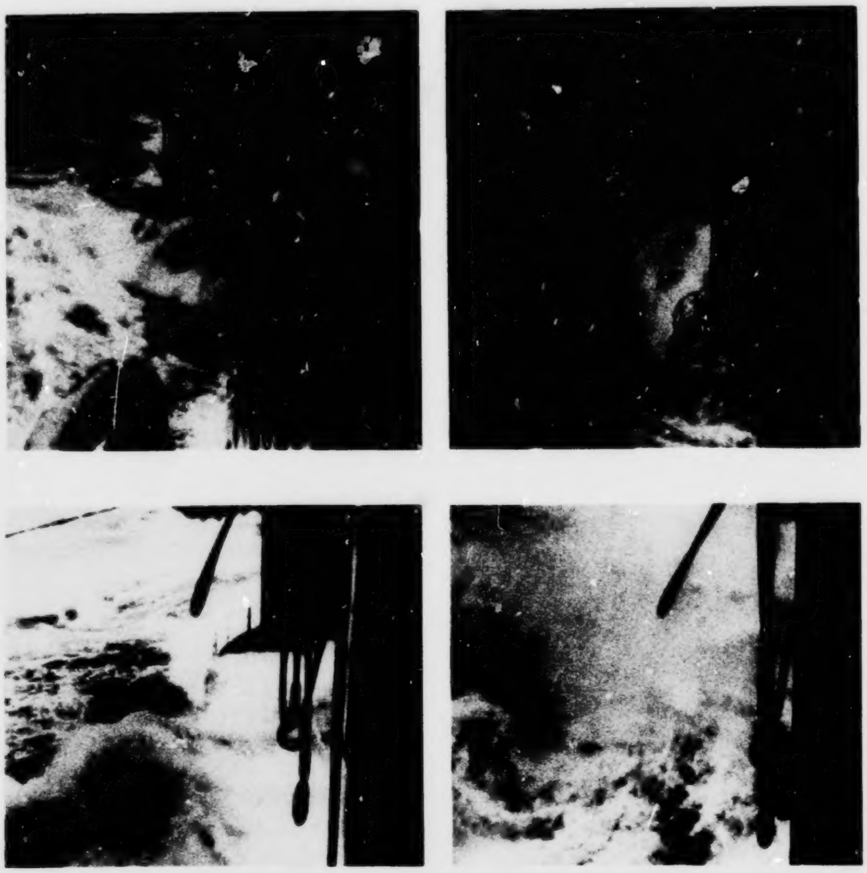
[2] Horikawa, K. *Coastal Engineering – An Introduction to Ocean Engineering* (University of Tokyo Press, 1978) pp. 97-100.

7.2 These photographs show the ballast control console and the view of the draft marks from porthole #3 at the extreme left.

Testimony indicated that, surprisingly, the failure of the portlight would not of itself be regarded as of sufficient importance to report to shore until the following day when it would be included as part of the daily routine commentary on equipment status. This may explain the complete absence of communication between the toolpusher and shore-based ODECO personnel. Similarly, Graham, when first advised by Jacobsen at 8:45 p.m. of the broken portlight, did not regard the event as significant, presumably because of the lack of concern expressed by Jacobsen. During a later conversation at 10:00 p.m. he was again reassured by Jacobsen that the *Ocean Ranger* was not in any difficulty as a result of the breakage. It is also surprising that at no time was there any mention of damage resulting from the incident, even though overheard VHF conversations indicated damage to or malfunctioning of the public address system and gas detection panel, and probably the ballast control panel. In fact, when the toolpusher requested a status report shortly before 10:00 p.m., the ballast control operator replied that "everything was okay", and this was relayed by Jacobsen to Graham as "all systems are functioning normally." The inaccuracy of these reports has been clearly demonstrated by the evidence. The differences between the reported and actual conditions can be attributed to an inaccurate assessment of the situation by the crew and to a lack of appreciation of the potential danger. The resulting lack of accurate and timely reports of the damage from those on board has hampered the investigation of the loss and led to a greater need for assumptions and deductions than would otherwise have been necessary.

The conclusions regarding the effect of the water on the equipment in the ballast control room are drawn from the VHF radio conversations overheard between 8:00 p.m. and 10:00 p.m., from the examination of the mimic panel and switches recovered from the wreck and from the ASE tests of new switches identical to those recovered. Of those who overheard portions of the VHF radio conversations, no one sensed any degree of urgency or felt any concern. Indeed nobody attempted to contact the rig to inquire about the problem. These conversations were all internal to the *Ocean Ranger* and represent communication between participants in the clean-up and the repair process and those in command. They provide a reliable indication of the thinking of those on board and, although the accuracy of testimony regarding the exact content and time of the conversations may be questionable, there is no doubt as to their general tenor.



7.3 This sequence of photographs shows the ballast control room portholes obscured by spray during relatively light sea conditions. The photographs were taken from the windlass control house at the mooring platform on the starboard bow.

The conversations dealt with the clean-up of the ballast control room and the condition of the equipment in the room. The participants stated that water and glass had to be cleaned up and that the gas detection panel and the public address system were not working. Reference was made to "the panel" being wet, and to the fact that someone, probably the electrician, was "working on it" and "had the cover off." Comments were made warning personnel of the potential for electric shocks and a request was made for maintenance personnel to come to the control room. There is no indication in these conversations that the crew felt any sense of danger. Clearly, they believed that whatever problems were being encountered had been defined and were under control.

It is manifest, however, that an inaccurate assessment by the crew played a significant role in the tragedy. While the crew were aware of the danger to those attempting to clean wet electrical equipment, they were unaware of the potential effect of sea water on the operation of the ballast control system. This ignorance of the workings of the ballast control equipment and of the unknown danger to the rig present within its components was, in all probability, the reason for the failure to report the damage to shore. In the final analysis, it was this ignorance which led to action which contributed to, rather than prevented, the loss of the rig.

DAMAGE TO THE BALLAST CONTROL CONSOLE

Examination of the recovered mimic panel and switches provided a reliable indication of the distribution of water and of the extent of damage to the ballast control panel. Testing indicated that those indicator light bulbs which did *not* fail survived because sea water elsewhere in the switch provided an alternate path for the 115-volt current, other than passing through the 24-volt bulb filament, thus protecting the filament from the effects of overvoltage. These intact bulbs were distributed randomly across the panel indicating a wide horizontal distribution of water. None of the damaged bulbs had been replaced, and the potential for continued short circuits within the switch housing indicates that the 24-volt indicator light circuit was never restored to normal operation. Another indication of the effects of sea water on the mimic panel was the burning and melting damage found at the plastic base of switch P-19 which controlled a remotely operated valve on the discharge side of the port drill water pump. This damage was caused by the collection of sea water at the base of the switch in a quantity sufficient to maintain a short circuit for the time necessary to cause the melting to the extent that was found. There was no indication of any attempt to replace this switch which, as recovered, was inoperable.

One 18-volt bulb in each pump switch pair was found to have failed, again because of an application of excess voltage, in this case, within the pump switch itself. Ingress of water into the affected pump switches required a wide horizontal distribution of water across the panel. Only 10 of the 24 individual pump switches were completely assembled when recovered and, of these, only the switch pairs controlling port pumps #3 and #5 were complete. Fourteen switches were without the coloured lens and in some cases the lens guard as well. The absence of the lens makes the switch difficult to operate. It is apparent from the condition of these switches that they had not been restored to normal operating condition before the abandonment of the rig.

The tests carried out by ASE on new valve control switches to determine their susceptibility to sea water demonstrated that the water would immediately affect the indicator light circuit. This effect would be caused either by a bridging of the contacts at the base of each light bulb, or by a bridging of the lower stems of those contacts located within the switch housing itself. Water could be removed from the bulb contacts at the base of the bulb by removing the push-button plunger and drying the switch cavity. It would be impossible, however, if a number of switches were affected, to remove water from within the switch housing itself in the time available to the crew. The soldered connections at the base of the switch were accessible with some considerable difficulty from the underside of the mimic panel. Without breaking these soldered connections, it was not possible either to lift the switch assembly away from the mimic panel or to disassemble the switch to remove water from inside the housing.

The ASE tests also confirmed that water can enter the microswitch located in the base of the valve control switch and cause a short circuit which will open the corresponding remotely operated valve if and when both the electrical and air supplies to the panel are activated. The opening of an appropriate combination of these valves would allow water to enter one or more ballast tanks from the sea or permit gravitation of ballast from one tank to another; for example, opening the remotely operated sea chest valve (#32) and the manifold valve (#20) in one pontoon plus any ballast tank valve in the same pontoon will permit sea water to flood into that particular tank. The opening of any two ballast tank valves in the same pontoon will permit gravitation between these tanks depending on the relative quantities of water in the tanks and the attitude of the rig.

Counsel for ODECO pointed out that the microswitches recovered from the rig showed no evidence of arcing, burning, or sea water shorting. He argued, as noted earlier, that little water had entered the ballast control room and that consequently no microswitches had ever been short-circuited by sea water. Although it was not possible to determine from an examination of the recovered microswitches if water had entered the switches before the capsize,[3] the ASE tests clearly indicated that water can readily enter and short-circuit these switches. It is concluded that water did in fact enter a number of microswitches in the mimic panel. Once water enters a microswitch, it is virtually impossible to remove the water without physically taking the microswitch out of the switch housing and subjecting it to prolonged drying. The evidence is clear that the microswitches were not removed from the switch housing nor disassembled in any way and that any water that entered the microswitches was still present at the time of the loss.

The susceptibility of the ballast control console and its components to sea water damage was, as indicated earlier, a deficiency in its design. Had all the components been sealed and designed for a marine application, the potential for water penetrating the switches would have been eliminated. The mimic panel was designed to allow the operator to control the valves and pumps by switches and to monitor their operation by the indicator lights. The damage to the panel affected the operation of both the monitoring and control circuits. Had these functions been designed to operate separately, the potential for human error would have been significantly reduced.

The testimony and technical evidence permit a number of firm conclusions to be drawn concerning the events of February 14 and 15, 1982. In the absence of direct evidence, however, some conclusions are based on assumptions derived from established patterns of behaviour and practice.

The probable immediate response of the ballast control operator to the portlight failure received a great deal of attention during the public hearings. All deadlights were found closed during the dive survey. It is generally agreed that the operator's first reaction would have been to close the deadlight on the damaged porthole to prevent more water from entering the room. He would probably have been immediately confronted with a ballast control panel that was unlit, with the exception of the 115-volt source light and possibly the lights in one or more of the pump switches. The sea water would have created immediate short circuits of most, if not all, of the lights by collecting either at the light contacts or in the switch housing. These short circuits would have increased the normal load up to 20 times and blown the fuse in the 24-volt light circuit[4].

It is unlikely that the operator on duty would have immediately turned off the electrical supply or the air supply to the panel, as both of these actions would have necessitated opening the ballast control console with the risk of touching wet electrical equipment. The operator would normally have called for assistance using the public address system, but it was disabled by sea water. The hand held VHF radio in the control room was used to report that there was water and glass in the room and the toolpusher, Thompson, ordered the crew "to get down there and get it cleaned up." The electrician would have quickly turned off the electric power to the panel, probably by means of the circuit breaker within the panel itself, or perhaps at the emergency switchboard located in the generator room at the lower deck level.

The overheard VHF radio conversations included reports to the toolpusher concerning the status of the equipment in the ballast control room. Reference was made to the malfunction of the public address system and the gas detection panel and to shocks, or the potential for shocks, from other equipment. One comment related to "valves opening by themselves." Other testimony indicated that there was a reference to valves "opening and closing." Because of the electrical circuitry of the ballast control console, it is not possible for a valve to close electrically on its own after it has been opened by short-circuiting.[5] Under normal operations, the valve closes and stays closed once the "close" switch is momentarily depressed. After water has entered the microswitch in the "open" switch, however, the "close" switch must be manually depressed and held in place in order to close the valve. The valve would otherwise return to the open position as soon as the push button was released.

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[3] Examination of the tested switches which short-circuited revealed no evidence of arcing or burning damage and accordingly the condition of the recovered microswitches of itself neither confirms nor rejects the possibility of water entry.

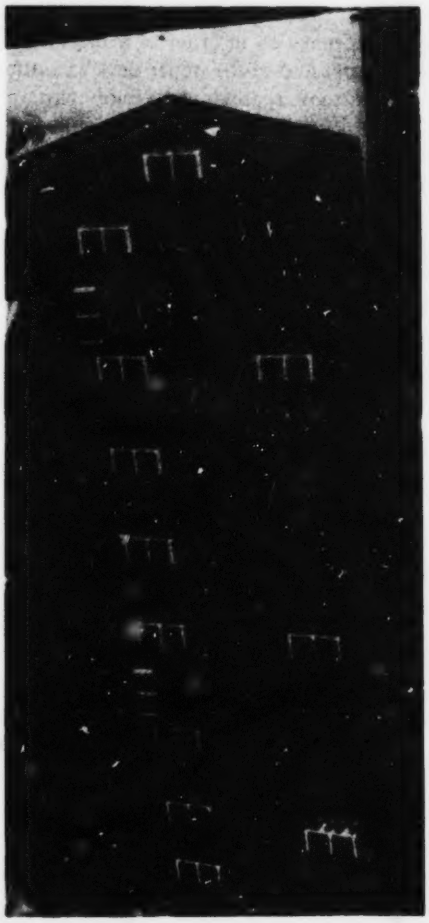
[4] The 24-volt light circuit feeding the indicator lights was fused with a 20-amp fuse on each side of the line. Each bulb normally carried a current of .04 amps. A sea water short circuit creates a current load at each short circuit of .6 to .8 amps. Short circuits at approximately 30 sites would thus be sufficient to overload the circuit and blow the fuse.

It is believed that, whatever the words used in relation to "the valves opening by themselves", the ballast control operator reacted to a random flashing or extinguishing of the valve position indicator lights. Within minutes he reported that "everything was okay." The statement that valves were opening could have been caused by either:

1. random flashing and dimming of bulbs as they failed due to overvoltage supplied from the 115-volt circuit, probably due to a short circuit at switch P-19, or

2. random microswitch shorting leading to the extinguishing of lights as valves commenced to open (only if the 24-volt circuit were operative).

Either of these effects is possible but the first is more probable. The immediate reaction of the operator, when he saw the indicator lights changing, would be to think that the valves were opening. The failure of any green ("open") light to come on within 20-40 seconds, perhaps coupled with shutting off the electric power to the panel, would lead the operator to report that the valves were okay. While one or more microswitches may have been shorted during this brief interval before the removal of electric power, there is no evidence of any change in the rig's attitude at this time. It is judged that if any remotely operated valves did open, they did not permit a significant amount of water to enter into or gravitate between the ballast tanks. It is, however, likely that in the few minutes before power was cut off a short circuit created by water at the base of switch P-19 caused 115 volts to leak into the 24-volt indicator light circuit resulting in the failure of 64 unprotected lightbulbs through overvoltage. George Granger, an *Ocean Ranger* electrician, testified that he believed that the crew would probably conclude that the problem lay with the indicator lights, caused by water collecting at the electrical contacts at the base of each light bulb.



7.4 One of four mimic panel sections recovered from the wreck. Several of the plexiglass insets from the panels were dislodged and lost during salvage.

According to the VHF conversation the crew were first occupied in cleaning up the water and glass and examining the condition of the equipment in the ballast control room. After an assessment of what was wrong with the ballast control console, the first action of the electrician would be to remove the covers from the 192 switches[6] and indicators on the mimic panel and dry each lamp holder and switch cavity, a task which would take several hours. The electronic technician would also be present in the control room, assessing and repairing as required the public address system and the gas detection panel. Since none of the indicator lamps was replaced and 14 of the 24 pump switches were found disassembled in the recovered panel, it is apparent that the maintenance operation was not completed by the time the rig was abandoned.

ODECO counsel suggested that in view of the report by Jacobsen at 10:00 p.m. that everything was functioning normally, the ballast control console had by then been restored to normal operation. This report, together with Jacobsen's comment that the anchor tensions were in the 240,000 lb. range, cannot be taken at face value. In the prevailing storm conditions the anchor tensions would differ widely, while the condition of the recovered panel clearly indicates that at no time following the portlight breakage was it restored to normal operating status.

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[5] The microswitch in the "open" switch was wired in a "normally open" configuration. A short circuit in this microswitch would have the same effect as if the switch were pressed by the operator. The microswitch in the "close" switch was wired in a "normally closed" configuration. A short circuit in this microswitch would have made it impossible to close the associated valve by pressing the switch.

[6] The mimic panel included 168 valve position indicator lights and 24 pump switch lights.

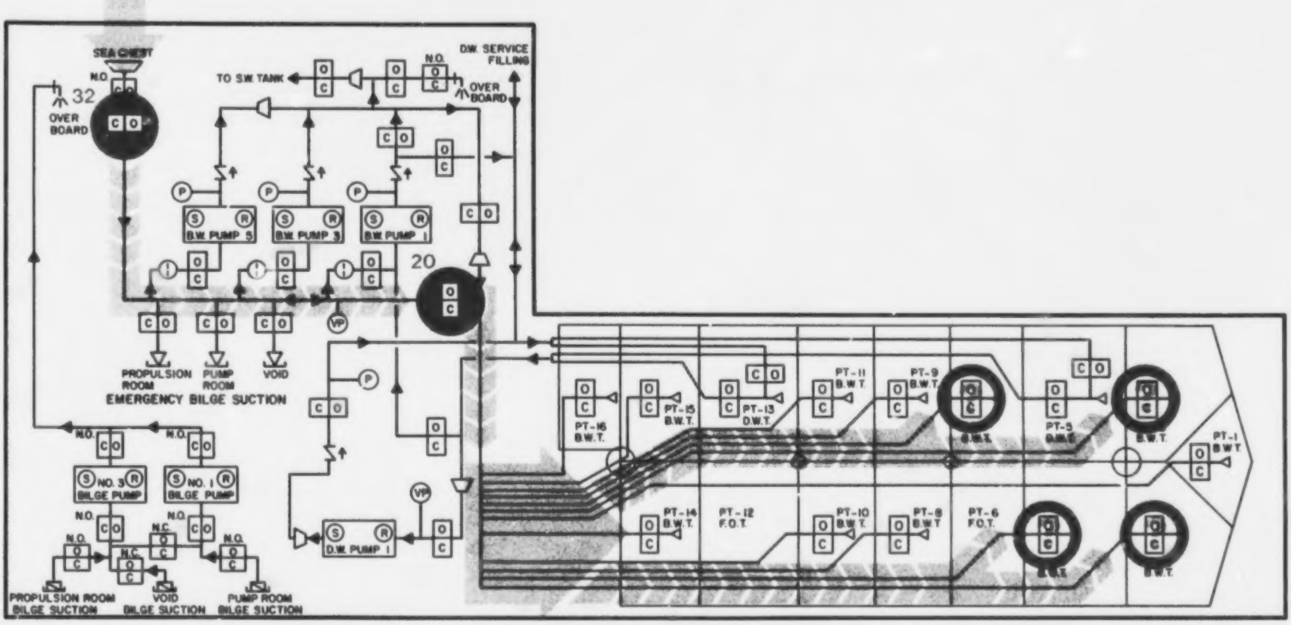
ODECO counsel went on to suggest that the *Ocean Ranger* was deballasted to a 72-foot draft sometime after 10:15 p.m. on February 14 in order to avoid further damage to the portlights in the ballast control room and to the upper deck structure and equipment, and that this deballasting which took approximately one hour was achieved by pumping out port and starboard tanks #10. The operation would have been carried out with the mimic panel functioning normally, although some or all of the indicator lights would not have been lit. He argued that this conclusion was based on the results of the model test program in which a capsize was only achieved from a 72-foot draft and on the tank soundings, particularly that of ballast tank PT-10.

Attempting to reproduce the capsize was one of the most difficult elements of the model test program and only one out of the 88 applicable tests resulted in the model capsizing (Appendix F, Item 5). It is determined that the rig was unlikely to have capsized at a draft greater than 80 feet. It would appear, therefore, that the capsize occurred at a draft between 80 feet and 72 feet. All attempts to reconcile the results of the tank soundings with the tank contents in the stability report of February 14 have, as noted earlier, been inconclusive. It would appear that during the capsize and subsequent sinking of the rig the contents of individual tanks underwent considerable change due to flooding through the vent lines or transfer of contents through open or leaking valves or possible damage to the bulkheads between the tanks. There is also evidence of some degree of error in the soundings themselves, either in the location of the air/water interface or in the measurement of the water depth to the keel. The possibility of error is particularly evident in the case of PT-10, since when the volume of air remaining in this tank was extrapolated to provide the equivalent air volume at the sea surface, the resulting volume was greater than the volume of the tank. It was decided on the basis of these factors that the tank soundings were not sufficiently reliable to form the basis for conclusions regarding the loss of the rig.

THE INITIAL LIST

It has been concluded that the electrical supply to the panel was restored between 12:30 and 12:45 a.m. The reason for doing this will never be known with certainty, but it is possible that it was done to permit an evaluation of the condition of the bulbs in both the valve switches and the pump switches. Testimony indicated that it is impossible to ascertain with the naked eye whether a bulb filament is broken or not. Accordingly, electric power would be required to evaluate the condition of the lights. It is also possible that the panel was reactivated, although without indicator lights, to deballast to a shallower draft in order to prevent damage to the subsea equipment as a result of increasing heave or to counteract the changing direction and intensity of the wind and waves. Documentary evidence indicates that, as recorded by the *Zapata Ugland*, heave continued to increase until midnight, while the recorded heave on the *SEDCO 706* reached its maximum at 11:00 p.m. It is possible that the *Ocean Ranger* may have been similarly affected but, as noted earlier, the rig had never previously deballasted for this reason. If the crew had slackened the leeward anchor lines, however, in response to increasing anchor line tensions, or if they had dumped or shifted any drilling mud, drillwater, fuel oil or deckload because of the severe storm conditions, it may have become necessary to operate the ballast system to counteract the shifting of these forces or weights.

Whatever may have been the reason behind the action, the restoration of power allowed random microswitch short circuits to open the corresponding remotely operated valves. It is known that the rig incurred a sudden port bow list, and it is concluded that the cause of this list was an ingress of water from the sea into the port


SEA CHEST
N.O.
32
OVER BOARD
TO S.W. TANK
N.O.
D.W. SERVICE FILLING
OVER BOARD
B.W. PUMP 5
B.W. PUMP 3
B.W. PUMP 1
20
VP
PROPULSION ROOM
PUMP ROOM
VOID
EMERGENCY BILGE SUCTION
N.O.
NO. 3 BILGE PUMP
NO. 1 BILGE PUMP
N.C.
D.W. PUMP 1
PROPULSION ROOM BILGE SUCTION
VOID BILGE SUCTION
PUMP ROOM BILGE SUCTION
PT-16 B.W.T.
PT-15 B.W.T.
PT-13 D.W.T.
PT-11 B.W.T.
PT-9 B.W.T.
B.W.T.
PT-5 B.W.T.
B.W.T.
PT-1 B.W.T.
PT-14 B.W.T.
PT-12 F.O.T.
PT-10 B.W.T.
PT-8 B.W.T.
PT-6 F.O.T.
B.W.T.
B.W.T.

7.5 The accidental opening of ballast valves P-32 and P-20 allowed sea water to enter the common manifold leading to the port pontoon tanks. Open valves leading to one or more forward tanks rapidly lead to a 4-5 degree list by the port bow.

pontoon. For this to have happened, the short-circuited microswitches must have included at least P-32 (the remotely operated sea chest valve), P-20 (the cross-over or manifold valve) and at least one forward ballast tank in the port pontoon. The opening of these three valves would lead to an immediate ingress of water from the sea into a forward port ballast tank. The incident of February 6 involved inadvertent flooding from the sea during pumping and an adverse port heel of 6 degrees resulted within minutes.[7] Without the countervailing pumping the reaction of the rig to an ingress from the sea would of course be significantly faster.

Observing the list, the ballast control operator would again have removed power from the panel, thus closing any open valves within 20-40 seconds. Before the removal of power, even if only minutes had passed, sufficient water would have entered the port pontoon to cause a port heel and probably a 4 or 5 degree trim by the bow. This trim, combined with the natural pitch and roll of the rig which probably exceeded 4 degrees in the prevailing sea and wind conditions, would give a maximum forward inclination of 8-10 degrees, the figures reported by Jacobsen to Graham at 1:00 a.m. The call by Jacobsen, however, was an "alerting" call only, with no reference to a Mayday or evacuation at that time, indicating that whatever the problem the crew believed that it could be isolated and rectified. Once power had been removed, any valves which had opened would close and the rig would appear to stabilize. Steps would then be taken to restore the rig to an even keel. The first and obvious remedy would be to try to pump out the port bow tank or tanks.

As previously noted, ODECO counsel argued that the microswitches did not in fact short-circuit. He suggested rather that at approximately 12:30 a.m. February 15, the ballast control operator inserted 18 manual control rods as a precautionary measure to ensure that the valves stayed closed. As previously discussed, the crew wrongly believed that insertion of a rod would close a valve. The reverse was true. Computer calculations prepared by Mr. Ralph Loomis, an ODECO engineer, indicate that after insertion of the brass rods gravitation between tanks would eventually cause a severe bow trim of 18-22 degrees, at which point the chain lockers and forward upper hull spaces would be vulnerable to flooding. This gravitation would occur almost imperceptibly for approximately 20 minutes and thereafter the trim would progress at approximately one degree per minute until gravitation had been completed. A trim of 6-8 degrees would have been reached after approximately 30 minutes. Reacting to the inclination as soon as it became evident, the ballast control operator would then have removed the electrical power from the panel. The tank level gauges in the ballast control room would have been confusing as they did not give an accurate reading when the rig was trimmed and showed apparent transfers of ballast when none had occurred. ODECO counsel suggested that power would then have been restored to the panel in order to operate the pumps and bring the rig back to a level attitude.

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[7] A discussion of this incident is found in Chapter 4.

It is difficult to accept the argument by ODECO counsel that the ballast control operator would insert the manual control rods as a precautionary measure if the ballast control console was operating normally. The operators on board had never used the rods and accordingly it is highly unlikely that they would have used them particularly when, as suggested by ODECO, deballasting had been completed and no further ballasting operation was required or anticipated. The insertion of the rods as a precautionary measure suggests a degree of planning and thought that is not consistent with the manner in which the rods were actually used. Since the crew must have recognized that there were not enough rods to complete the task, it is not logical to suggest that they would be used to carry out a planned operation. The insertion of three rods into solenoid valves affecting drill water tanks also suggests a hasty rather than a planned activity. Furthermore, the crew knew that the simple alternative of removing power from the panel would cause all valves to close. It was unlikely therefore that they would resort to a previously unused precautionary measure. If the rods had been inserted as a precautionary measure after the use of the panel for one hour to deballast, it would have been contrary to the established patterns of behaviour of the ballast control operators under normal conditions. Furthermore, since counsel for ODECO suggests the panel was functioning normally, the insertion of the rods would have been the only unusual action taken affecting the panel. It is likely, therefore, that the insertion of these rods would have been seen as contributing to the cause of the trim, in which case the crew would undoubtedly have removed them. The evidence shows that none of the rods was in fact removed and that the crew was "trying to isolate the problem." Insertion of the rods as found could result only in gravitation. This changes the longitudinal moment of the ballast but has no effect transversely; a forward movement of water in the port pontoon would cause a forward trim, but not a port heel. The reports of a port list are inconsistent with difficulties caused only by gravitation and no water ingress. The rig must, therefore, have been subject to ingress of water from the sea, not gravitation alone as suggested by ODECO.

7.6 One of the six banks of solenoid valves recovered from the ballast control console. Many of the brass rods were broken during salvage, leaving only the brass bushing and a section of the threaded rod at the front of the valve housing. The valve on the extreme right is fitted with a plastic dust cap.

THE CREW'S COUNTERMEASURES

Considering the events that flowed from the restoration of power to the panel between 12:30 and 12:45 a.m., the crew may well have thought that an electrical malfunction had occurred in the switching system. With the February 6 incident fresh in their minds, their course of action would have been to prevent additional ingress from the sea and then pump out. Since the panel had malfunctioned and, in their opinion, valves had opened, the crew would have taken the prudent course of closing both manual sea chest valves before reapplying power to the panel to operate the pumps. The closing of these valves would have prevented any further ingress of sea water. The crew would have believed that the condition of the rig had been stabilized, and that no harm would result from reactivating the panel. While under other conditions the possibility of gravitation between tanks may have been considered, it is unlikely that this would have been considered possible if the pumps were running at the same time.

The absence of indicator lights would not necessarily have prevented the crew from reactivating the panel in order to pump out. An inclination reaching 8-10 degrees in bad weather would be a frightening condition and restoring the rig quickly to an even keel would be a priority.[a] Furthermore, the pumping operation was not complex, requiring only the opening of four valves to pump out of one tank with one pump. The other action taken would be to reassemble one or more pump switches. On the recovered panel, only the switches for pumps #3 and #5 on the port side were completely assembled. The crew apparently intended to pump from the port side of the rig. These switches were reassembled although the red or "stop" lights in both switches were broken. With the manual sea chest valves closed, power was restored and the appropriate valve and pump switches depressed to commence pumping from one or more forward port tanks, probably with the use of one pump initially. No indicator lights would be visible or lit, with the possible exception of the green "run" light for the pump. The restoration of power would once again allow short circuits in any affected microswitches to open ballast valves. The switches for the port aft tanks were in close proximity to the broken portlight and it is highly probable that the microswitches controlling the valves for one or more of tanks P-14,15 and 16 were short-circuited. On the morning of February 14, PT-15 and 16 were 100% full, while PT-14 was 67.9% full. PT-10 and 11, both aft of the centre line, were also 100% full.

With the rig inclined 8-10 degrees by the port bow and with the aft tanks being closer to the pump room than the forward tanks, any attempt to pump out of a forward tank would be futile as long as a full or partially full stern tank was open to the suction line. The water would be drawn from the stern tank first and the effect would be to increase the bow trim and raise the mean draft of the rig. The crew would observe that the pump suction and discharge gauges and ammeter were indicating a positive flow of water but that the bow trim was still progressing. The probable response would be to add another pump. This would increase the rate of pumping from the stern tanks and would accelerate the rate of trim.

The pumping rate would determine whether forward gravitation would occur in the port pontoon between tanks with open valves. There is no evidence of pumping from the starboard pontoon and accordingly gravitation between any inadvertently opened tanks in this pontoon was more likely. Any forward gravitation which did take place would of course serve only to accelerate the rate of forward trim. That pumping from the port pontoon was attempted and was to some degree successful is supported by the fact that when the ***Boltentor*** approached the stern of the ***Ocean Ranger***, the rig appeared to be level transversely. The earlier port heel had apparently been substantially corrected and the only reasonable conclusion is that this was achieved by pumping water out of that pontoon.

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[a] The incident of February 6 resulted in the crew being alerted to proceed to lifeboat stations.

7.7 One of the four mimic panel sections recovered from the ballast control console. Only the pump switches for port pumps #3 and #5 had been reassembled.

The pumping operation or planned pumping operation was perhaps relayed by Jacobsen to Graham at 1:00 a.m. In talking to SAREC immediately following his conversation with Jacobsen, Graham says:

> "Yes and they're down eight to ten feet. They are trying to ballas(t) – trying to isolate-ah-ah-what the problem is, but-ah-so far they haven't-ah-haven't been able to make it. Ah-they just don't know where-where the problem is."

While Graham had no recollection of his reference to "ballasting", since he repeats Jacobsen's reference to "feet" and "isolating the problem", it is more probable than not that Jacobsen had mentioned "trying to ballast." Since the countermeasures of closing the manual sea chest valves and pumping were proving ineffective, the *Seaforth Highlander* was called at 1:05 a.m. to come closer and as the trim progressed, the Mayday was issued at 1:09 a.m.

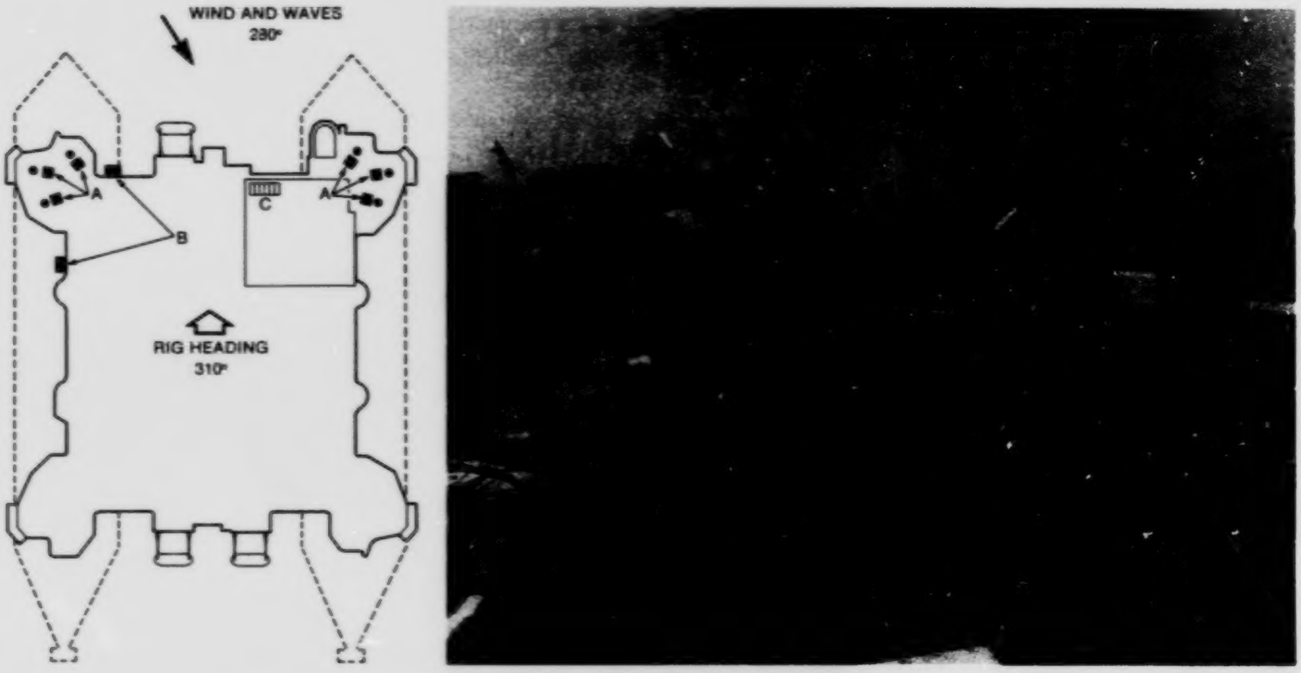
At this point the crew would have been at a loss to explain the increasing trim and would think perhaps of structural damage or valves being unintentionally opened. The pumps would be left running as the first line of defence and the brass manual control rods inserted in an effort to close valves which were thought to have stuck open. In fact, insertion of the rods opened the valves.

Many people have pondered the configuration of the inserted brass rods in an attempt to find some logic or evidence of the crew's intention. It is agreed generally that there is no explanation for the configuration found other than a last minute attempt to close any and all valves. The rods were inserted from the right side of the solenoid bank, where the box of rods was located, to the left side.

Another possible explanation is that as the crew thought that there were problems with valves "stuck open" they decided to leave open only those tanks necessary to pump out the port side. The insertion of the brass rods shows some confusion over the solenoid valves applicable to the drill water tanks, but generally the starboard ballast tanks are "closed" as are the majority of the port aft tanks. The reason for not "closing" all the port aft tanks may well be that there were insufficient rods. The rod inserted in port forward tank 2 is inexplicable.

In any event, the insertion of the manual rods would cause any relevant valves not already opened to open, thus adding to the potential for forward gravitation and an increasing trim. At or before 1:09 a.m., the crew would have observed that despite pumping, closing both manual sea chest valves and "closing" the majority of the ballast tank valves, the condition was worsening, and accordingly reported a severe port list of 12-15 degrees as "progressing." The model tests indicated that at this point chain locker flooding would commence, accelerating the rate of trim.

As the forward portion of the upper deck became lower, its cargo and deck fittings became exposed to the severe wave action. Drill pipe and storage huts were washed overboard and air vents leading to the sack storage area in the lower deck were broken, allowing water to flood into the lower deck area. One of these vents was located on the bow on the port side, while another was located on the port side forward. It is believed that one or both of these vents were broken off by wave action or by shifting deck cargo. It is also likely that water flooded from the lower deck into the column spaces above the chain lockers, into the accommodation areas through damaged portions of the superstructure and thence into the lower deck area, and into the lower hull tanks through exposed vent lines. Whether or not any of this damage and flooding occurred before the decision to abandon is unknown. The flooding would have created an unstable situation and the *Ocean Ranger*, dynamically assisted by wave motion, capsized and sank at approximately 3:15 a.m., February 15, 1982.



7.8 The illustration shows the location of the chain locker openings (A), the ventilators (B) and the accommodations area stairwell (C); the photograph shows one of the large bow ventilators which led to the sack storage area below. With a severe port bow list, drill pipe and deck cargo would have shifted, causing damage to the ventilator and allowing sea water to flood the lower deck.

CONTRIBUTING FACTORS

Of the three rigs operating on the Grand Banks on February 14, 1982, only the *Ocean Ranger* was lost. The individual factors contributing to the loss had lain dormant on the rig throughout its working life, but it was their unique active combination on February 14-15, 1982, which caused the tragic event. Various aspects of the *Ocean Ranger's* design made the rig more vulnerable than it should have been: the exposed location of the ballast control room; the weakness of the portlight; the lack of protection against sea water of the mimic panel; the lack of an adequate manual control system in the control room and the vulnerability of the chain lockers to flooding. Aspects of the management system were also contributory factors: lack of proper procedures for emergencies, lack of manuals and technical information relating to the ballast control console and lack of adequate training programs for key personnel. Human error, lack of knowledge of the vulnerability of the rig and its ballast system and a mistaken reaction to the malfunction of the equipment compounded these design shortcomings and led directly to the disaster. Closing the deadlights in the ballast control room before the storm intensified would clearly have prevented the loss. Even after the portlight had broken, knowledgeable action by the crew in dealing with the effects of the sea water on the ballast control console would have averted the tragedy.

Each event and action which contributed to the loss of the *Ocean Ranger* was either the result of design deficiencies or was crew-initiated. The disaster could have been avoided by relatively minor modifications to the design of the rig and its systems and it should, in any event, have been prevented by competent and informed action by those on board. Because of inadequate training and lack of manuals and technical information, the crew failed to interrupt the fatal chain of events which led to the eventual loss of the *Ocean Ranger*. It is, nevertheless, the essence of good design to reduce the possibility of human error and of good management to ensure that employees receive training adequate to their responsibilities.

The following is a summary of the contributing factors:

1. The design decision to locate the ballast control room in the third starboard column below the lower deck.

2. The failure to assess the potential loading on the portlight and to specify material of sufficient strength.

3. The failure in design to protect the ballast control console and its components for use in a marine environment where sea water ingress was a possibility.

4. The failure of the crew to close the deadlights in the ballast control room when confronted with the severe storm conditions.

5. The lack, on the part of the crew, of a sufficient understanding of and appropriate information on the way in which the ballast control system functioned to permit an accurate and timely assessment of the actual and potential effect of an application of sea water to the ballast control console. Shutting down both the air and electrical supplies to the console and then using only one of these power sources at any given time would have permitted the safe and temporary operation of the valves while the panel was being tested and repaired. A restoration of both sources of power to the panel shortly before 1:00 a.m. on February 15, 1982 created the initial trim from which the rig did not recover.

6. The interconnection between the control and monitoring circuits of the ballast system which caused problems for the operator.

7. Lack of a well understood alternate method for operating the ballast valves from the ballast control room. The brass manual control rods, if correctly used, provided an alternate means of controlling the ballast valves in the event of an electrical fault in the panel, but their use was not officially recognized nor was it documented.

8. The crew's misunderstanding of the operation of the manual control rods and lack of appreciation of the extent to which ballast water could transfer or gravitate from one ballast tank to another. The insertion of the manual control rods achieved an effect opposite to that intended by the crew and accelerated the progression of the bow trim.

9. Lack of an installed secondary communications system linking the ballast control room to the pump rooms which, in the event of a failure of the public address system, could have provided a means of co-ordinating the manual operation of the ballast system from the pump rooms.

10. Lack of appreciation by the ballast control operator that a forward trim would increase if one or more valves leading to the aft tanks were open while pumping from a forward tank was attempted.

11. Lack of protection for the chain lockers against ingress of sea water, lack of an alarm system to warn of any downflooding that did occur and lack of effective means of dewatering the chain lockers in that event.

12. Failure of the watertight integrity of the upper hull by reason of the vents and the light structure of the accommodation area.

8

EVACUATION AND EMERGENCY RESPONSE

CHAPTER EIGHT EVACUATION AND EMERGENCY RESPONSE

At 1:30 a.m. on Monday, February 15, the *Ocean Ranger* informed Mobil's shore base and the *SEDCO 706* that its crew was going to lifeboat stations and that the rig was being evacuated; half an hour earlier (1:00 a.m.) the rig had requested assistance. This chapter, a continuation of the description of events in Chapter 5, describes the emergency response to the *Ocean Ranger's* 1:00 a.m. request for assistance, the actions of the personnel on the *Ocean Ranger* immediately before the evacuation notice, and the actions of those on and off shore who participated in the response.[1]

The first indication given to personnel on shore by the *Ocean Ranger* that a serious problem had developed was at 1:00 a.m. when Jack Jacobsen advised Merv Graham that the rig was listing and that the cause of this list could not be determined. Jacobsen requested Graham to alert the Canadian Coast Guard. Graham, who received the call at home via the MARISAT system, agreed and also undertook to muster the air and marine resources under contract to Mobil. Immediately after finishing his call, he telephoned the Search and Rescue Emergency Centre (SAREC) in St. John's[2] at 1:06 a.m. and told them the *Ocean Ranger* was listing to the bow and the cause of this list was not known. He informed SAREC about the number of crew on the rig, the weather conditions and the positions of the three supply boats and the two other rigs in the vicinity of the *Ocean Ranger*. He also told them that he would arrange for the supply boats in the area to proceed to the rig and that he would alert Universal Helicopters which were under contract to Mobil. He did not request direct assistance from SAREC at this time, but indicated that Jacobsen might contact them later.

Meanwhile, on board the *Ocean Ranger*, a Mobil foreman had directed the standby boat *Seaforth Highlander* to come to close standby at 1:05 a.m.; a distress telex was sent to the U.S. Coast Guard Rescue Coordination Center (RCC) in New York at 1:09 a.m. and a Mayday, on 2182 kHz, was dispatched at approximately 1:10 a.m. The *SEDCO 706* recorded picking up this Mayday. Jacobsen called the *SEDCO 706* at approximately 1:11 a.m. and asked the radio operator to issue Mayday relays for the *Ocean Ranger*. He also briefed Keith Senkoe on the emergency and requested that he dispatch the supply boats which were on standby to the *SEDCO 706* and to the *Zapata Ugland*. This call was monitored at Mobil's shore base where at 1:14 a.m., the radio operator Rick Flynn, called SAREC.

Flynn advised SAREC that the *Ocean Ranger* was experiencing a list and that evacuation appeared necessary. He said the crew had attempted to send a Mayday and had requested a Mayday relay from the *SEDCO 706*, adding that the helicopters under contract to Mobil had been alerted. During this telephone conversation, Flynn maintained radio contact with the *Ocean Ranger* and both Flynn and SAREC heard Jacobsen say to the *SEDCO 706* that the rig was "... 'listing ... and not coming back for us so we need every helicopter in the air we can get out here ...." His voice during this conversation was surprisingly calm. SAREC and Flynn also overheard the *SEDCO 706* agree to the request for assistance from the supply boats. The SAREC controller, who could not speak directly with Jacobsen, used Flynn as an intermediary to request the wind direction and speed, and the number of vessels in the area. Jacobsen replied that winds were from the west with gusts up to 80 miles per hour and that there were three supply vessels in the area. Jacobsen discontinued this transmission at 1:17 a.m. This was the last time Jacobsen talked to Mobil's shore base.

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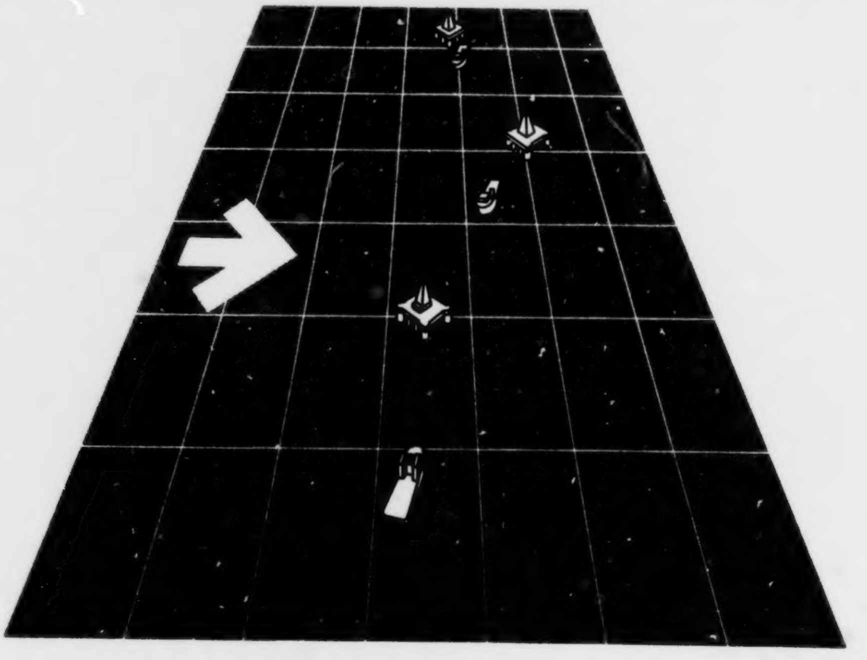
[1] A list of the major participants is given at the end of this chapter.

[2] For the purposes of this report, all references to SAREC refer to the St. John's location.

At 1:20 a.m. Graham contacted Rod Fraser, Mobil's drilling foreman on the *SEDCO 706*, and appointed him Mobil's on-site co-ordinator. He advised Fraser that Mobil's helicopters were alerted and told him to dispatch the standby vessels, the *Boltentor* and the *Nordertor*, to assist the *Ocean Ranger*. He also told Fraser to monitor all radio communications and report events immediately to shore.

At 1:21 a.m. SAREC notified the Rescue Co-ordination Centre (RCC) in Halifax of the *Ocean Ranger*'s distress. RCC Halifax advised SAREC that they had just been informed of the situation by RCC New York. At the same time the *SEDCO 706* dispatched its standby vessel, the *Boltentor*, to the aid of the *Ocean Ranger*; the *Zapata Ugland's* standby vessel, the *Nordertor*, was sent on the same mission at 1:22 a.m.

At 1:30 a.m. Ken Blackmore, the night radio operator on the *Ocean Ranger* called Mobil shore base and said that the crew were going to lifeboat stations and requested that another Mayday relay be transmitted. After acknowledging what was to be the final transmission from the *Ocean Ranger*, Flynn immediately informed SAREC: "The crew of the *Ocean Ranger* is gone to lifeboat stations now ... [and] ... they're getting the *706* [to] relay another Mayday for them". Flynn again advised SAREC that the helicopters under contract to Mobil had been alerted and that all of the supply boats in the area of the *Ocean Ranger* had been directed to ren-



8.1 By 1:30 a.m. all three vessels had been directed to assist the *Ocean Ranger*. The *Nordertor* (top), dispatched from the *Zapata Ugland* at 0122 NST, was approximately 20 miles away, and the *Boltentor* (centre), dispatched from the *SEDCO 706* at 0121 NST, was approximately 9 miles away. The *Seaforth Highlander* (bottom) had been called to close standby at 1:05 a.m., and was approximately 6 miles from the rig.

0130 NST (0500Z)
The telex connection with the *Ocean Ranger* is broken.

der assistance. RCC New York noted that at 1:30 a.m. the MARISAT telex connection with the *Ocean Ranger* was broken; several attempts to regain the connection were unsuccessful.

On the *Boltentor*, second mate Malcolm Martin overheard the last radio transmission from the *Ocean Ranger*. Immediately after this transmission the *Boltentor* was called by the *SEDCO 706* and advised that the situation was now more serious and that they should proceed to the *Ocean Ranger* as soon as possible. Martin then directed the seaman on watch to alert the captain and the remainder of the crew. Within a few minutes Captain Davison came on the bridge and assumed command. The *Boltentor* was now travelling at approximately 6 knots. The second standby vessel, the *Nordertor*, was at this time about 20 miles northeast of the *Ocean Ranger*'s position travelling at approximately 9 knots.

0131 NST (0501Z)
RCC Halifax calls the 103 Rescue Unit at Gander to mobilize for a rescue mission.

At 1:31 a.m. RCC Halifax contacted Captain Rudolph Preus, duty officer for 103 Rescue Unit[3], at his home in Gander, Newfoundland. RCC Halifax advised Preus of the emergency on the *Ocean Ranger* and told him to have his helicopter crew, all of whom were at home, mustered for the rescue mission. In St. John's, Mobil personnel had alerted the Universal Helicopter crews. The Royal Canadian Mounted Police (RCMP) were contacted to arrange ground transportation for them because of the severe snow storm conditions in the city.

At 1:36 a.m. RCC Halifax asked SAREC in St. John's to have Coast Guard radio issue an All Ships Broadcast on behalf of the *Ocean Ranger*. The All Ships Broadcast was not issued by the Coast Guard radio station in St. John's (VON) until 2:04 a.m.

At 1:46 a.m. Captain Preus advised RCC Halifax that the helicopter crews for 103 Rescue Unit had been alerted and were proceeding to the airport. He conferred with weather forecasters at Gander and received actual weather observations for Gander, St. John's, and the rigs at Hibernia. He concluded that the low ceiling at Gander (800 feet) would make it necessary for him to fly through clouds enroute to St. John's, and that the forecast of "rime icing" in clouds meant that the helicopters could not fly. Preus advised RCC Halifax that his departure to St. John's would be delayed until the winds abated and the weather conditions improved.

STANDBY VESSELS

Meanwhile, the three standby vessels were proceeding towards the *Ocean Ranger* and reporting their relative positions to the *SEDCO 706*. Fraser, the on-site coordinator, testified that he advised the masters of each standby vessel that the *SEDCO 706* would receive and log all communications and relay the information to St. John's via the MARISAT system. As the standby vessels drew closer to the *Ocean Ranger*, they began to prepare equipment which might assist in a possible rescue. On the *Seaforth Highlander*, first mate Rolf Jorgensen and several crew members prepared the following rescue equipment:

1. a cargo net (12 feet by 9 feet)[4];
2. a grappling hook;
3. a boat hook;
4. two heaving lines (approximately ½ inch in diameter and 50-60 feet in length with monkey fists on the end);

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[3] 103 Rescue Unit is a Search and Rescue Unit stationed at Gander, Newfoundland, equipped with three Labrador/Voyageur helicopters.

[4] The cargo net, which was laid out on the afterdeck to be used as a scramble net was not fastened down and was washed overboard before any rescue attempt was made.

5. two life ring lines (approximately ½ inch in diameter and 100 feet in length spliced around two life rings);[5]

6. a Sampson rope (approximately 1 to 1½ inches in diameter and 70-80 feet in length with a thimble on the end).

After completing their preparations, the crew of the *Seaforth Highlander* gathered on the bridge and awaited instructions from the *Ocean Ranger*. The second mate, Jerry Higdon, testified that he made several unsuccessful attempts to contact the rig on VHF. The only radio communications overheard were the Mayday relays emanating from the *SEDCO 706*.

The *Seaforth Highlander* was heading in a northeasterly direction on a course which would take her to the *Ocean Ranger's* stern. The visibility on the bridge was limited by heavy seas and blowing snow, but, as she approached the *Ocean Ranger's* position, the rig came into sight. Jorgensen testified that it was fully lit, but that it was impossible to see whether or not it was listing. At that time, the *Seaforth Highlander* was approximately 3000 feet from the rig. As she moved closer, clusters of white lights and smoke flares were visible off the port beam. Upon inspection it was determined that these lights were attached to life preservers floating on the water. The life preservers were empty. The *Seaforth Highlander* was now, according to Jorgensen, only 1200 feet from the rig. The time, according to Captain Duncan, was 1:50 a.m. A distress flare was then sighted off the starboard quarter.

This evidence presented by crew members of the Seaforth Highlander *was inconsistent with events logged by other participants in the rescue attempt. The testimony of Captain Duncan regarding the time of his arrival at the* Ocean Ranger *and the sighting of the flare is in conflict with the logs of the* SEDCO 706 *and the testimony of Fraser. The* SEDCO 706 *log shows that at 1:55 a.m. Duncan reported his vessel to be three miles from the* Ocean Ranger *and that at 2:07 a.m. there were many flashing lights in the water. The log of the* SEDCO 706, *Fraser's personal log, the log entries of SAREC (St. John's), the personal log of Graham, and the logs of the* Nordertor *and the* Boltentor, *indicate that Duncan is in error. It is, therefore, concluded that the* Seaforth Highlander *made visual contact with the* Ocean Ranger *at 2:11 a.m. and the distress flare which Duncan stated he saw at 1:50 a.m. was actually seen at 2:14 a.m.*

0221 NST (0551Z)
The *Seaforth Highlander* spots a lifeboat and proceeds towards it.

A second distress flare was sighted along with the lifeboat from which it had originated. At 2:21 a.m. the *Seaforth Highlander* reported to the *SEDCO 706* that it had spotted a lifeboat and was proceeding toward it. This information was immediately passed on to Mobil's shore base and to SAREC. Graham testified that he issued instructions to Fraser to advise the masters of the supply vessels not to secure lines to lifeboats. In his testimony Graham explained that he was aware of an incident in the Gulf of Mexico in which a lifeboat had capsized while under tow. Fraser stated that the instructions were relayed to the supply vessels, but both Higdon and Duncan testified that they did not receive these instructions; nor did the other supply boats, the *Boltentor* and the *Nordertor*, have any record of receiving them.

The lifeboat which had fired the flare was approximately 1200 feet downwind of the *Seaforth Highlander*. Duncan testified that it was riding low in the water with its bow into the prevailing seas. He decided to position his vessel downwind of the lifeboat. He also decided to place her stern into the wind and waves. Duncan explained that with the bow into the seas his vessel's superstructure would act as a sail and force the *Seaforth Highlander* off its heading, thus creating the possibility of a collision with the lifeboat. He stated that his bow thrusters, which were used to keep the vessel in position, did not have sufficient power to hold his vessel in position under the sea conditions that existed at that time. He also stated that from the aft

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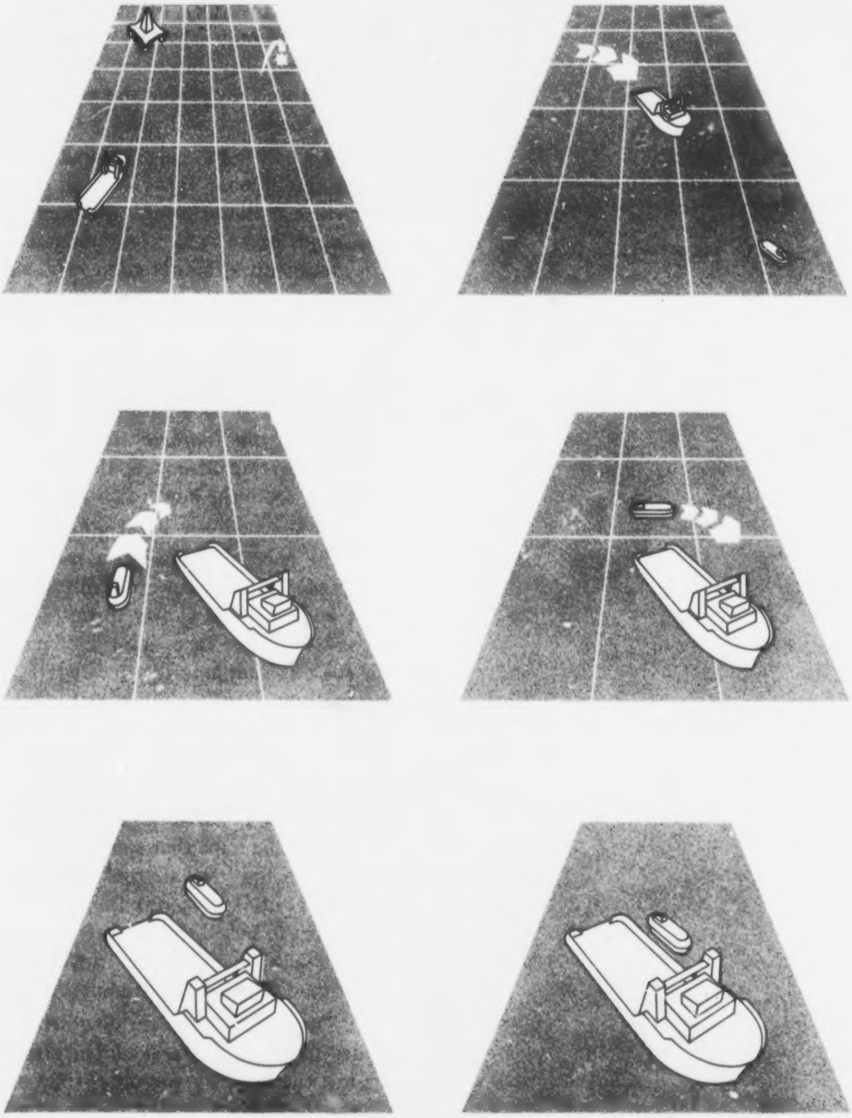
[5] These heaving lines and life ring lines were improvised from a coil of polypropylene rope which the *Seaforth Highlander* had in store.



8.2 The *Seaforth Highlander* approached the port stern of the *Ocean Ranger* and subsequently manoeuvred to the assistance of a lifeboat.

control console he would have a full view of the aft deck from which all rescue attempts would be handled and that he could also keep an eye on the oncoming sea.

As Duncan was manoeuvring his vessel into position, four seamen (Eric Rees, Bert Woolridge, Kenneth Lidstone and Dennis Chaytor) and the first mate, Jorgenson, went outside onto the afterdeck. The lifeboat was now clearly visible and obviously damaged. The bow of the lifeboat was holed on both sides of the stem from the waterline to the gunwale. Seaman Rees testified that he watched the lifeboat as it moved from the starboard side of his ship, around the stern and up the portside to a position amidship of the *Seaforth Highlander*. He stated that he saw men bailing water. Jorgensen testified that the lifeboat was under power, and apparently steered by a man who stood in the aft hatch.

The sea conditions at this time were extremely rough. Duncan stated that the swells exceeded 60 feet and there were 15-foot breaking waves. The seamen on the afterdeck testified that the seas were breaking over the stern of the ship and that the spray froze instantly, hampering their visibility and movement.[6] They were standing between the bulwarks and crashrail on the *Seaforth Highlander's* port side, and to improve mobility they removed the lifelines which secured them to the bulwark. As a consequence they placed themselves in danger of being washed overboard or smashed against the bulwarks by heavy seas crashing over the afterdeck.

0232 NST (0602Z)
The lifeboat is now alongside the Seaforth Highlander

At 2:32 a.m. the *Seaforth Highlander* reported the lifeboat to be alongside. Inside the lifeboat lights were on and men could be seen moving about. Some of the men were bailing through the port and starboard side doors. The sound of the seas and winds made voice communications between the lifeboat and the seamen on the afterdeck impossible. Higdon, who was monitoring the radio, stated that there were no radio communications from the lifeboat. On the afterdeck, seaman Woolridge attempted to throw a Sampson rope to the lifeboat, but it was blown away from its target. Woolridge then threw a line, with a life ring attached, to a man in the aft hatch of the lifeboat. The man caught the line and made it fast to a handrail on the canopy of the lifeboat; Jorgensen tied the other end of the line to the crashrail on the port side of the *Seaforth Highlander*. Meanwhile, seaman Rees threw a second line with a life ring attached; this line was made fast to the lifeboat by a man who appeared from the bow hatch and to the crashrail of the *Seaforth Highlander*.

While this was happening, seven or eight of the men in the lifeboat emerged onto the port gunwale. These men were wearing hard hats and either work vests or life preservers; some were lightly clad while others wore heavier clothing. The lifeboat began to roll slowly to port, away from the *Seaforth Highlander*, and within seconds capsized throwing the men who had been standing on the port gunwale into the sea and snapping the lines which had been attached to the *Seaforth Highlander*. As the men from the lifeboat spilled into the sea, the water in the immediate area was illuminated by the lights attached to the life preservers. The lifeboat had completely capsized. The time was 2:38 a.m.

0238 NST (0608Z)
The lifeboat capsizes.

Second mate Higdon and a seaman then left the bridge and joined the crew on the afterdeck to assist in the rescue attempts. Jorgensen told two seamen to launch a life raft in the hope that some of the men in the water would be able to climb aboard. Launching the life raft took some time because its securing lines were frozen and had to be cut. The men in the water, however, were immobilized and unable to make any effort to board the life raft or grasp lines thrown to them and within their reach. Stormy seas, inadequate retrieval equipment, and the immobility of the men in the water made the rescue attempts futile.

During this time the *Seaforth Highlander* kept her stern to the wind and continued to take heavy seas on her afterdeck. The crew were forced to brace themselves against the bulwark and other solid objects to avoid being washed overboard. In spite of the hazardous and difficult conditions on the afterdeck, Jorgensen narrowly missed grasping a man who was washed against the port side of the supply vessel. One or two of the men in the water were able to hold onto the capsized lifeboat longer than the others. The lifeboat was very close to the ship's port propeller and Captain Duncan decided to shut down this propeller for fear it would injure the men in the water. This reduction in power combined with strong winds and high waves forced his vessel off location. He was able to manoeuvre her back within 50-70 feet of the capsized lifeboat. By this time the men in the water had drifted downwind and attempts to retrieve them were unsuccessful.

The crews of the other standby boats approaching the *Ocean Ranger* were made aware of the severity of the emergency by the reports from the *Seaforth Highlander*. The masters directed their crews to prepare any equipment on board which

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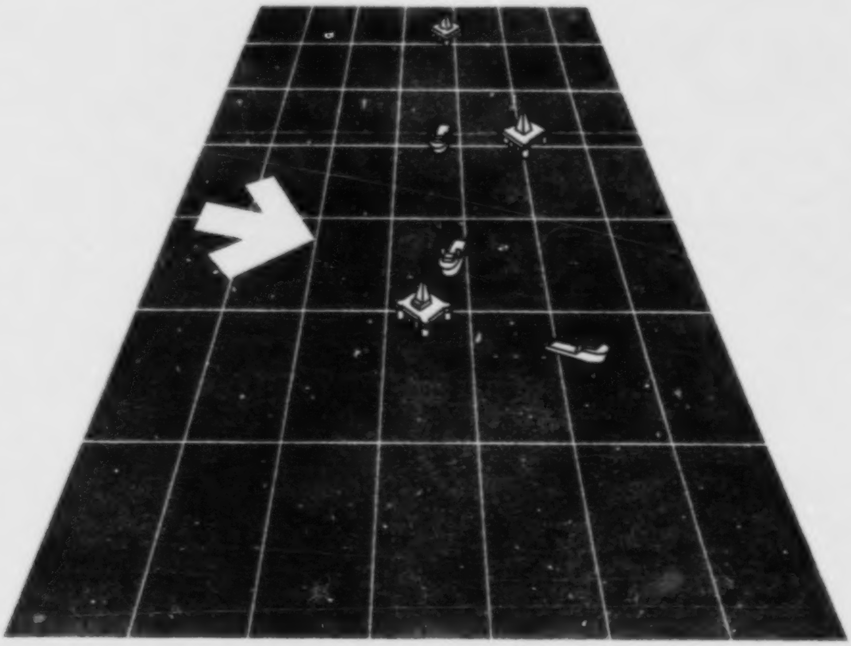
[6] The evidence revealed that the crew of the *Seaforth Highlander* did not have suitable clothing for working outside in severe weather conditions which hampered their mobility. They wore coveralls which were not waterproof and provided little insulation. Some of them wore rubberized oil slickers over the coveralls but they became extremely wet and cold during that night's rescue attempts.



8.3 The *Boltentor* arrived at the *Ocean Ranger* at 2:45 a.m. and reported that helicopters could land on the rig. Approximately fifteen minutes later the *Nordertor* lost radar contact with the *Ocean Ranger*.

0245 NST (0615Z)
The *Boltentor* makes visual contact with the *Ocean Ranger*.

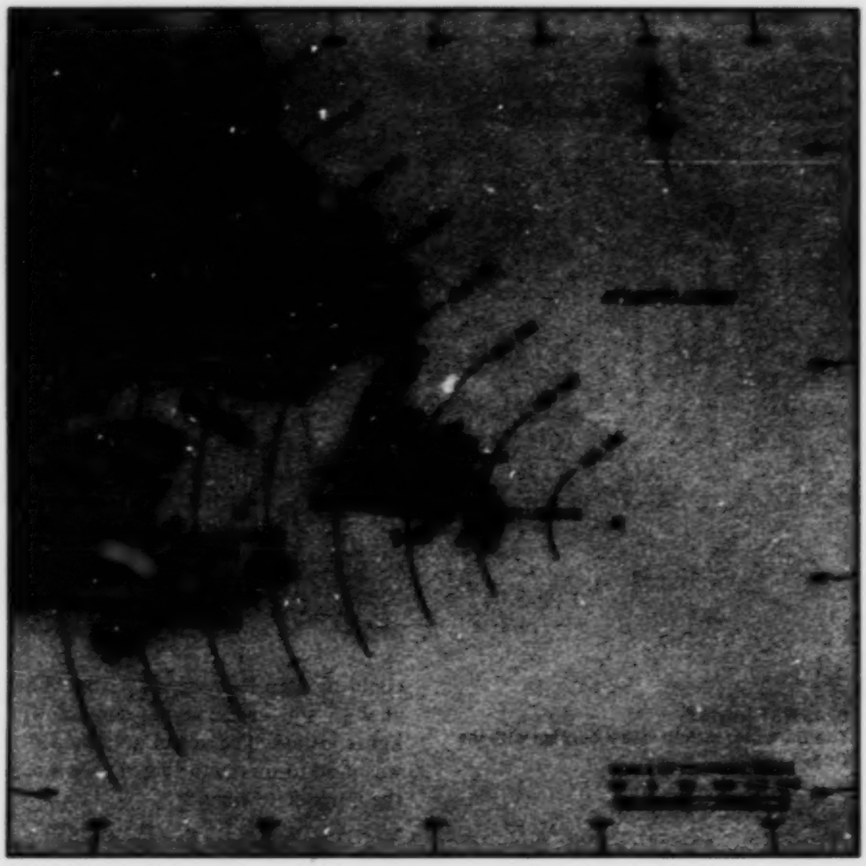
could be used to rescue survivors. The *Boltentor* was the second vessel to arrive and at 2:45 a.m. made visual contact with the *Ocean Ranger*. There were only a few lights visible. The vessel approached the rig's starboard quarter and a search light was used to survey the rig. There was no sign of life or lifeboats, either on board or in the immediate vicinity.

The *Boltentor* had been asked by the *SEDCO 706* to determine whether a helicopter could land on the deck of the *Ocean Ranger*. Captain Davison manoeuvred his vessel along the starboard side to its stern and concluded that the rig was sufficiently level to permit a helicopter to land. Several deckhands, however, testified that, from their vantage point, the rig had a severe trim with the helicopter deck almost in the water and exposed to breaking waves. At 2:55 a.m. the *Seaforth Highlander* requested the *Boltentor's* assistance in recovering the capsized lifeboat. At this time the *Seaforth Highlander* was approximately 1-1½ miles downwind of the *Ocean Ranger*.

0300 NST (0630Z)
(Approximate)
Radar contact is lost with the *Ocean Ranger*.

In the meantime the *Nordertor* was proceeding at 8-9 knots towards the *Ocean Ranger*. Captain Allingham said that during his vessel's approach he picked up the rig on radar and maintained radar contact until 3:00 a.m., when the rig disappeared from the screen. He also testified that, after the rig had disappeared from radar, two small blips appeared briefly in the same location on the radar screen. Five minutes later, he checked with the *Boltentor* and the *Seaforth Highlander* to find out whether they still had radar contact with the *Ocean Ranger*. Both replied that radar contact had been lost. At 3:38 a.m. Allingham reported to the *SEDCO 706* that the *Ocean Ranger* was no longer visible on radar. This information was immediately relayed to Graham at Mobil's shore base; it was decided that Mobil's shore base would advise SAREC. The evidence, however, revealed that SAREC was not informed until 7:35 a.m. that the rig had disappeared and was presumed sunk.

As the *Boltentor* approached the *Seaforth Highlander*, Captain Davison observed bodies and a capsized lifeboat in the water. The crews of the *Boltentor* and the *Seaforth Highlander* made repeated attempts to rescue possible survivors using lifebuoys and grapnels, but the 60-70 knot winds and the 50-60 foot seas rendered



8.4 The locations of the Search and Rescue aircraft tasked to the *Ocean Ranger* site by the Rescue Co-ordination Centre in Halifax.

0340 NST (0710Z)
The *Nordertor* arrives and joins the search effort.

rescue efforts futile. At 3:40 a.m. the third standby vessel, the *Nordertor*, arrived and joined the rescue. The masters of the three supply vessels then began to co-ordinate their search effort. Based on their assessment of the prevailing wind and seas they developed drift plots and concentrated their searching downwind of the *Ocean Ranger's* last position.

AIRCRAFT

While Mobil's supply vessels were searching for survivors, aircraft support was mustered by Mobil and RCC Halifax. In St. John's, the Universal helicopter crews had arrived at the airport by 2:15 a.m. but according to the testimony of the co-pilot, Bruce Hutchings, high winds hampered their engineers from getting the helicopters out of the hangars, and a further delay was caused by the fueling of auxiliary tanks. The first helicopter was ready at 3:15 a.m. and was airborne at 3:22 a.m., with ODECO rig superintendent Counts aboard. At this time the weather conditions at the site of the accident were marginal with a 300-600 foot overcast ceiling, mixed rain and snow, and winds gusting to 69 knots. Captain Hutchings testified that under normal circumstances the helicopters would not fly in these conditions but because of the severity of the emergency the pilots decided to take this risk. In so doing they exhibited great courage.

0322 NST (0652Z)
Mobil-contracted helicopters depart St. John's.

Additional aircraft were dispatched to the *Ocean Ranger* site by RCC Halifax. The 103 Rescue Unit at Gander was "tasked"[7] at 1:31 a.m. but, as stated earlier,

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[7] Tasking occurs when RCC formally requests the assistance of primary and secondary SAR resources for a specific SAR mission. Once resources are tasked they depart as quickly as possible.

0415-0714 NST (0745-1044Z)
SAR aircraft support departs from Summerside, Prince Edward Island and Greenwood, Nova Scotia.

reported at 1:46 a.m. that adverse weather conditions prevented its helicopters from flying. At 2:24 a.m. 413 Rescue Unit at Summerside, Prince Edward Island, was "alerted"[8] and informed that aircraft would be required to provide communications and search support. At 3:00 a.m. RCC Halifax tasked a Voyageur helicopter stationed at Summerside to proceed to St. John's. This helicopter departed at 4:15 a.m. A Buffalo aircraft, also stationed at Summerside, was tasked at 2:24 a.m. and departed at 3:53 a.m. Additional air support was tasked at 4:40 a.m., when an Aurora aircraft[9] stationed at Greenwood, Nova Scotia, was appointed "On-Scene Commander"[10]; the Aurora departed for the accident site at 7:14 a.m. The first Search and Rescue aircraft from Summerside, the Buffalo, arrived in St. John's at 6:15 a.m.

0435 NST (0805Z)
The Mobil-contracted helicopters arrive on site.

The Universal helicopters arrived at the site of the accident around 4:35 a.m. but, because the helicopters were not equipped with retrieval equipment, their activities were restricted to directing supply vessels to lifeboats, life rafts, and bodies. The helicopters attempted to hover between 50 to 70 feet above the water, but had to pull up periodically, because high waves and breaking spray posed a threat to their safety. When the helicopters were landing on the *SEDCO 706* and *Zapata Ugland* to refuel, the pilots had to use extreme caution, because the heavy seas and strong winds caused the rigs to pitch and roll. The helicopters had to "hot refuel"[11] because the high winds did not permit the pilots to shut down the engines. Captain Hutchings stated that the winds were so strong that the refuelers had to crawl on the helideck with the assistance of lifelines. The helicopters stayed on the rigs until notification came that the SAR helicopters were on their way and that they could return to St. John's. At 6:00 a.m. they were airborne for the return trip.

The weather conditions at Gander improved in the early morning. At 6:00 a.m. the ceiling was 2000 feet, with 4 miles visibility and winds of 18 knots gusting to 25 knots. By 6:30 a.m. there was a 3000-foot ceiling and improved visibility of 12 miles but winds were gusting to 28 knots. At 6:30 a.m. and 6:50 a.m. the SAR helicopters departed for St. John's. Before their departure, the pilots received very little information on the accident. They were advised by a Universal Helicopter's dispatcher that the rig could not be detected on radar but they were given no pertinent information on the rescue effort. The SAR helicopters landed in St. John's shortly before 7:30 a.m. to refuel and receive updated information on the rescue effort.

Captain Clarke, one of the SAR helicopter pilots, testified that Mobil personnel at the airport had no knowledge of the activities of the supply vessels and did not know whether or not the rig was still upright, even though the *SEDCO 706* had been advised at 3:38 a.m. that radar contact with the *Ocean Ranger* had been lost. He stated that at that time not even RCC Halifax had any up-to-date information and that when he left St. John's shortly before 8:30 a.m. he did not know whether the *Ocean Ranger* was still afloat or whether survivors had been located and rescued. The two Universal helicopters arrived back in St. John's at 8:35 a.m. and reported that the *Ocean Ranger* had sunk. This was the first visual confirmation of the tragedy received by the Mobil and the SAR personnel at St. John's airport.

0835 NST (1205Z)
The Mobil-contracted helicopters land at St. John's and report that the *Ocean Ranger* has sunk.

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[8] An Alert is the first stage of a SAR incident. Resources which may be required to render assistance are advised of the incident.

[9] An Aurora is a military aircraft which is used in submarine detection and surveillance operations. The Aurora is fitted with sophisticated radio equipment and sensing devices which are useful during SAR incidents where multi-aircraft and vessel resources are used.

[10] The On-Scene Commander is designated to co-ordinate and control the search and rescue mission.

[11] Hot refuel is a fueling procedure used by helicopters whereby the rotor blades are not shut down. This procedure is required when wind speeds exceed either the shut down or start up limits of the helicopter.

SEARCH FOR SURVIVORS

The supply vessels continued their search throughout the night but sea conditions and inadequate retrieval equipment frustrated all efforts to recover bodies. At 7:00 a.m. the *Nordertor* spotted a capsized lifeboat with a life ring from the *Seaforth Highlander* attached to it. The *Nordertor* made several unsuccessful attempts throughout the morning to recover the lifeboat. On one of its recovery attempts the *Nordertor* retrieved the propellor and shaft of the lifeboat. During the final unsuccessful attempt to recover this lifeboat, Captain Allingham observed some 20 bodies strapped inside; several bodies floated out through a hole in the bow and one was washed onto the afterdeck of the *Nordertor*. Allingham stated that the lifeboat eventually disappeared and, in his opinion, sank. It was obvious from the life ring attached that this was the same lifeboat encountered by the *Seaforth Highlander* at 2:21 a.m.

0935 NST (1305Z)
First SAR aircraft arrives on site.

By 9:45 a.m. all the air support tasked by RCC Halifax had arrived. The Aurora assumed control and began to co-ordinate the search. The SAR helicopter from 103 Rescue Unit in Gander, commanded by Captain Clarke, had arrived at approximately 9:35 a.m. He spotted two lifeboats and two life rafts. One of the lifeboats was completely capsized while the other was observed to be holed and down on one end; the two life rafts were partially inflated and floating just below the ocean surface. Captain Clarke and his crew also observed bodies floating in the water in clothing that ranged from pajamas to the orange immersion suits worn by rig crews when they are being transported by helicopter. Captain Clarke attempted to recover one of the bodies dressed in an immersion suit by lowering SAR Technician Master Corporal Randy Brown on the SAR helicopter's hoist system. Brown was able to touch the back of the victim's life preserver but a breaking wave separated him from the body and prevented recovery. Brown reported that the body appeared lifeless and, except for resurfacing occasionally, was floating just below the ocean surface.

0946 NST (1316Z)
RCC Halifax tasks vessel support.

In addition to air support, RCC Halifax tasked vessels in the general vicinity of the accident and the Canadian Coast Guard Ships (CCGS) stationed in St. John's. At 9:46 a.m. RCC instructed SAREC to task the CCGS *Bartlett*. However, at 10:43 a.m. the *Bartlett* was released and CCGS *Sir Humphrey Gilbert* was tasked instead. It departed St. John's at 11:39 a.m. but because of the poor sea conditions and heavy winds the *Gilbert* estimated its arrival time at the *Ocean Ranger* site at 1:00 a.m. on Tuesday, February 16. While enroute, the *Gilbert* was reassigned to assist the *Mekhanik Tarasov*,[12] a Russian cargo vessel which was in distress in the vicinity of the *Ocean Ranger*.

RCC Halifax also tasked the *Gadus Atlantica*, a research vessel under charter to the Canadian Department of Fisheries and Oceans, at 10:42 a.m., February 15. The *Gadus Atlantica* was 119 miles from the accident site and estimated its arrival at 6:00 a.m., February 16. The *Java Seal*, a seismic vessel, was also tasked at 11:39 a.m. on February 15. Several vessels also responded to the 2:04 a.m. All Ships Broadcast from the Coast Guard Radio Station in St. John's but because of their distance from the site of the accident, most were tasked and then released.

The search efforts of the helicopters and supply vessels on Monday, February 15, were unsuccessful in locating survivors. Throughout the day supply vessels, assisted by aircraft, searched for lifeboats, life rafts, and bodies. With the exception of the one body recovered by the *Nordertor*, all vessels were unsuccessful in recovering additional bodies. Several visual inspections of lifeboats by SAR helicopters revealed no sign of life nor any sign of having been occupied.

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[12] The *Mekhanik Tarasov* sank at 5:00 a.m., February 16, 1982. A total of 32 crew members died. Five crew members, however, were successfully rescued by the Faroese fishing trawler *Sigurfari*. The Master of the Faroese trawler, Mikkjal Olsen, testified that the heavily clothed Russian seamen were in the water for approximately 20 minutes before they were recovered. With the exception of one, all were in a hypothermic condition and one died shortly after being recovered. Sea conditions at the time were rough and winds exceeded 45 knots.

8.5 A search area of over 6000 square miles was covered during the four days after the loss, through the combined efforts of both industry and government aircraft and vessels.

On Tuesday, February 16, the search efforts continued with support provided by the Aurora and two Buffalo aircraft. The CCGS *Bartlett*, still in St. John's, was retasked at 9:08 a.m. to replace the *Gilbert* which had been reassigned earlier to assist the Russian cargo vessel. Additional vessels had arrived to assist the *Boltentor* and the *Nordertor*. Throughout Tuesday, a thorough search of the area was completed; one body was recovered, and the *Nordertor* located and recovered an unoccupied lifeboat. The *Bartlett* arrived in the search area at 1:00 a.m. on Wednesday, February 17. At 4:30 p.m. that day, RCC Halifax formally requested that the search effort be reduced, and approval was received from SAR in Ottawa the following day. The search for survivors was discontinued at 11:10 p.m., Friday, February 19, although vessels in the area maintained a watch for bodies and debris for a number of days after. Two lifeboats and six life rafts were also recovered.

The search and rescue operations led to the recovery of 22 bodies from the 84-man crew with the last body recovered on February 20 by the *Boltentor* (Appendix G). Autopsy results indicated that in all cases the cause of death was drowning while in a hypothermic condition.

Personnel Named in Chapter 8
Alphabetical

NAME	POSITION	COMPANY
ALLINGHAM, Baxter	Master, *Nordertor*	Crosbie Offshore
BLACKMORE, Ken	Medic/Radio Operator, *Ocean Ranger*	ODECO
BROWN, Randy	SAR Technician, Gander	103 Rescue Unit
CLARKE, George	Aircraft Commander, Gander	103 Rescue Unit
CHAYTOR, Dennis	Seaman, *Seaforth Highlander*	Seaforth Maritime
COUNTS, Jim	Drilling Superintendent, St. John's	ODECO
DAVISON, James	Master, *Boltentor*	Crosbie Offshore
DUNCAN, Ronald	Master, *Seaforth Highlander*	Seaforth Maritime
FLYNN, Rick	Radio Operator, Mobil Base, St. John's	Harvey Offshore Services
FRASER, Rod	Drilling Foreman, *SEDCO 706* (On-site Co-ordinator of Rescue Mission)	Mobil Oil
GRAHAM, Merv	Area Drilling Superintendent, St. John's	Mobil Oil
HIGDON, Jerry	Second Mate, *Seaforth Highlander*	Seaforth Maritime
HUTCHINGS, Bruce	Co-pilot, St. John's	Universal Helicopters
JACOBSEN, Jack	Senior Drilling Foreman, *Ocean Ranger*	Mobil Oil
JORGENSEN, Rolf	First Mate, *Seaforth Highlander*	Seaforth Maritime
LIDSTONE, Kenneth	Seaman, *Seaforth Highlander*	Seaforth Maritime
MARTIN, Malcolm	Second Mate, *Boltentor*	Crosbie Offshore
PREUS, Rudolph	Aircraft Commander, Gander	103 Rescue Unit
REES, Eric	Seaman, *Seaforth Highlander*	Seaforth Maritime
SENKOE, Keith	Drilling Foreman, *SEDCO 706*	Mobil Oil
WOOLRIDGE, Bert	Seaman, *Seaforth Highlander*	Seaforth Maritime

Personnel Named in Chapter 8
By Location

ONSHORE	**OFFSHORE**	
St. John's	**Hibernia**	
	Ocean Ranger	*Seaforth Highlander*
GRAHAM, Merv FLYNN, Richard HUTCHINGS, Bruce COUNTS, Jim	JACOBSEN, Jack BLACKMORE, Ken	JORGENSEN, Rolf HIGDON, Jerry DUNCAN, Ronald REES, Eric WOOLRIDGE, Bert LIDSTONE, Kenneth CHAYTOR, Dennis
Gander	*SEDCO 706*	*Boltentor*
PREUS, Rudolph CLARKE, George BROWN, Randy	SENKOE, Keith FRASER, Rod	MARTIN, Malcolm DAVISON, James
	Zapata Ugland	*Nordertor*
	————	ALLINGHAM, Baxter

9

ANALYSIS OF EMERGENCY RESPONSE

CHAPTER NINE ANALYSIS OF EMERGENCY RESPONSE

The analysis of the response to the emergency that developed on board the *Ocean Ranger* on the night of February 14 and resulted in the loss of the entire crew includes the response of the crew on the rig as well as the response of both industry and government.

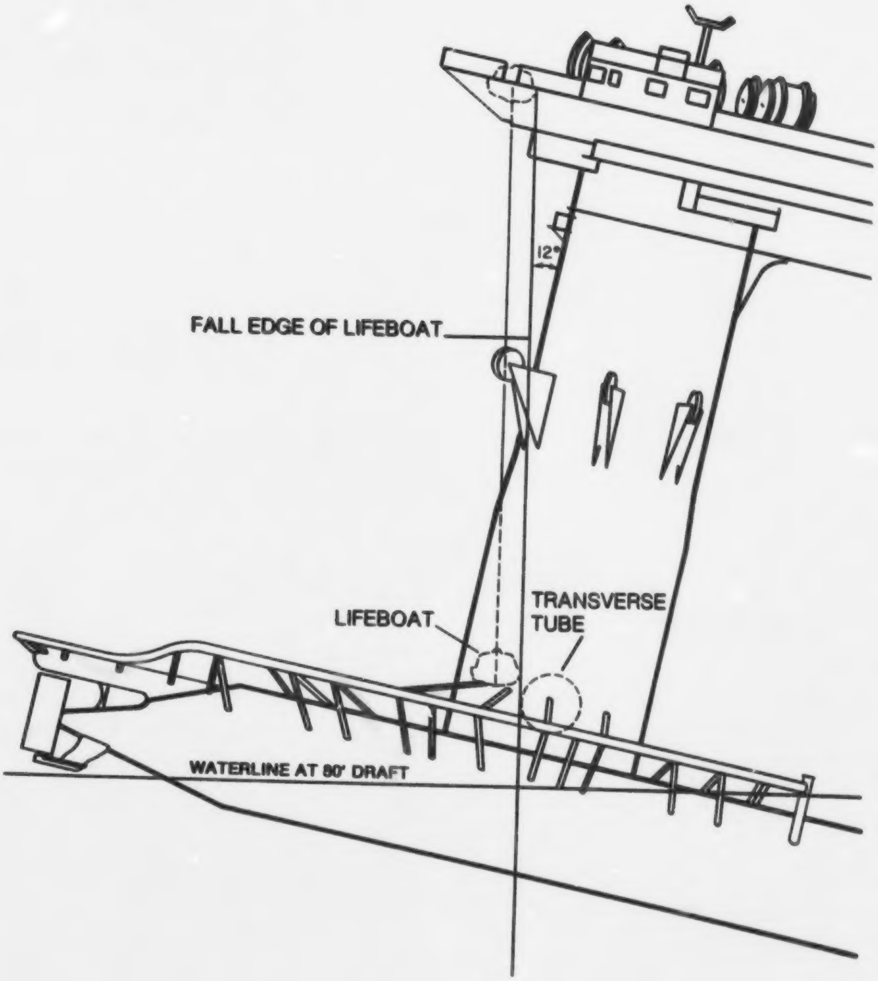
The last communication from the *Ocean Ranger* was at 1:30 a.m. when it was stated that the crew were going to the lifeboat stations. There is evidence to indicate that key personnel on board were unaware, up to the last hour, that a serious problem existed, and, when they did become aware, they may have thought they could remedy it as they remedied the severe list on February 6. When they began to realize, around 1:00 a.m., that the problem was beyond their ability to solve, they were minutes away from abandoning the rig and unable to give adequate warning to those who might have helped them.

There was no communication from Jacobsen or Thompson to their shore bases before 1:00 a.m. to indicate any realization of a serious situation nor did the VHF conversations overheard by personnel on the *SEDCO 706* earlier in the evening reflect serious concern. Senior personnel on the *Ocean Ranger* knew that their standby vessel, the *Seaforth Highlander*, was eight miles away, but they made no request until 1:05 a.m. for her to come to close standby. When the *Ocean Ranger* weather observer transmitted his report at 11:30 p.m., he gave no information other than routine weather observations. Even at 1:00 a.m. when Jacobsen spoke to Graham, there was no mention of a Mayday. That conversation did indicate that Jacobsen recognized possible danger and was giving an alert. But even at that late hour, he appeared to think that the situation was not beyond control. Whatever happened thereafter, happened quickly.

Little warning was given to the Mobil shore base. In fact, when the telex went out for help at 1:09 a.m., it was not in a proper form to depict the urgency of the situation since the word "Mayday" was not used. The telex, which had no addressee, went of necessity to the MARISAT operator in Connecticut who, after checking with the *Ocean Ranger*, directed it to the U.S. Coast Guard in New York, who later phoned it to RCC Halifax. Time would have been saved if the telex had been addressed to RCC Halifax. The telex was, however, interpreted and treated as a Mayday. After the dispatch of the telex, the *Ocean Ranger* attempted to send out a Mayday on the 2182 kHz distress frequency. Their messages were not picked up on shore, presumably because of the low power of their transmitter. The relays being sent out by the *SEDCO 706* were not heard initially for the same reason. When the transmission power was increased on the *SEDCO 706*, the Mayday relay was picked up by the Canadian Coast Guard station in St. John's at 1:45 a.m. but evidently not by any ship of passage.

When the seriousness of the situation was fully recognized around 1:15 a.m., the only resource available for evacuation was the lifesaving equipment on board the rig. The *Seaforth Highlander*, steaming towards the rig, was still over seven miles away. Helicopters were at least one hour flying time away and even under ideal weather conditions and at 30-minute standby, could not have arrived in time to evacuate the crew. Not all of the lifesaving equipment on board the rig was available to the crew at 1:30 a.m. The rig had by then developed a trim in excess of 15 degrees, with waves crashing over its bow, and the lifeboat located there would have been submerged most of the time, if not already smashed. It would in any case have been inaccessible. The only lifeboats accessible were the two located on the stern. The life rafts were also available at various locations on the upper deck, but their use that night was impossible.

How the crew left the rig is not known. The only definite evidence available is that 30 or more left in the Harding lifeboat positioned on the rig's port stern, the same lifeboat that came alongside the *Seaforth Highlander* and eventually capsized. It is not known whether the Watercraft lifeboat, also located on the stern, was launched nor whether a muster list existed for this recently installed boat. That lifeboat was not recovered. It is, however, known that at approximately 2:55 a.m. when the rig was last observed by the crew of the *Boltentor* no lifeboats were seen on the



9.1 This illustration is taken from the ODECO installation plans for the Watercraft lifeboats. The design limitation for safe launching is illustrated at a 12 degree bow trim. The pitch and roll of the rig in heavy seas would restrict safe launching to a much smaller angle.

stern. It is evident from the large number of bodies sighted in the vicinity by the supply vessels and the helicopters, that the crew had abandoned the rig. Whatever the means of evacuation adopted, it is evident that none was practicable or safe under the prevailing wind and sea conditions. When it became evident that the severe trim was beyond control, confusion may have developed in the rush to the lifesaving equipment and that may explain the light clothing on some of the bodies that were either recovered or sighted.

INDUSTRY RESPONSE

Industry's response to the disaster was primarily the responsibility of Mobil who controlled the supply vessels and the helicopters. Mobil's *Contingency Plans and Emergency Procedures* manual was designed to facilitate the mobilization of personnel and the co-ordination of communications and resources in the event of an emergency. Responsibility for initiating and supervising these functions rested, according to the manual, with the emergency communications officer who, on that night, was Merv Graham. It was his duty to summon key Mobil personnel in St. John's and to dispatch vessels and helicopters to aid the stricken rig. He also had to co-ordinate communication with the other rigs, the standby vessels and the helicopters under contract, and with SAREC in St. John's and RCC Halifax.

Graham, who was at home when he received the MARISAT call from Jack Jacobsen at 1:00 a.m., immediately alerted SAREC and instructed Ken Beattie, Mobil's logistics supervisor, to alert the helicopters and to go to the airport. Graham then told Rod Fraser, senior Mobil drilling foreman on the *SEDCO 706*, to dispatch the standby vessels of the other two rigs to the *Ocean Ranger*. He then proceeded to the Mobil shore base where a communication centre was manned on a 24-hour basis. He appointed Fraser as on-scene co-ordinator to organize the emergency response of the standby vessels and to channel communications to the shore base. Graham told Fraser that shore base would keep SAREC and the Canadian Coast Guard informed of developments.

Transcripts of the tape-recorded SAREC and RCC telephone conversations throughout the rescue operations, including those with Mobil personnel, were entered in evidence. It is apparent from a review of these transcripts that communications emanating from Mobil shore base were neither accurate nor prompt, with consequent confusion and delay. This was evident not only with respect to communications from the shore base to SAR agencies but even among Mobil personnel. The Mobil radio operator told SAREC that there were three ships in the area of the *Ocean Ranger* and that three or four "Chinooks"[1] were being dispatched to evacuate the crew. This information was inaccurate and may have influenced RCC's decision not to press additional SAR resources immediately into service. Mobil did not use Chinooks in their offshore operations, rather they had under contract from Universal Helicopters Ltd. three Sikorsky S-61s of which two were dispatched. As late as 5:27 a.m., SAREC was told by a senior Mobil employee that there was no real change in the status of the rig and that two standby vessels were at the scene. This is difficult to understand because the *Nordertor* reported at 3:38 a.m. that the *Ocean Ranger* had disappeared from radar. This information was not passed on by Mobil to SAREC until 7:35 a.m. and even later to Mobil personnel at the airport. In fact the pilot of one SAR helicopter testified that when he left Torbay airport around 8:30 a.m., Mobil personnel at the airport did not have any pertinent up-to-date information on the rescue efforts nor did they know whether the rig was afloat or had sunk.

It is evident that Mobil's key personnel had not practised their emergency procedure roles to gain an understanding of what they would be required to do in the

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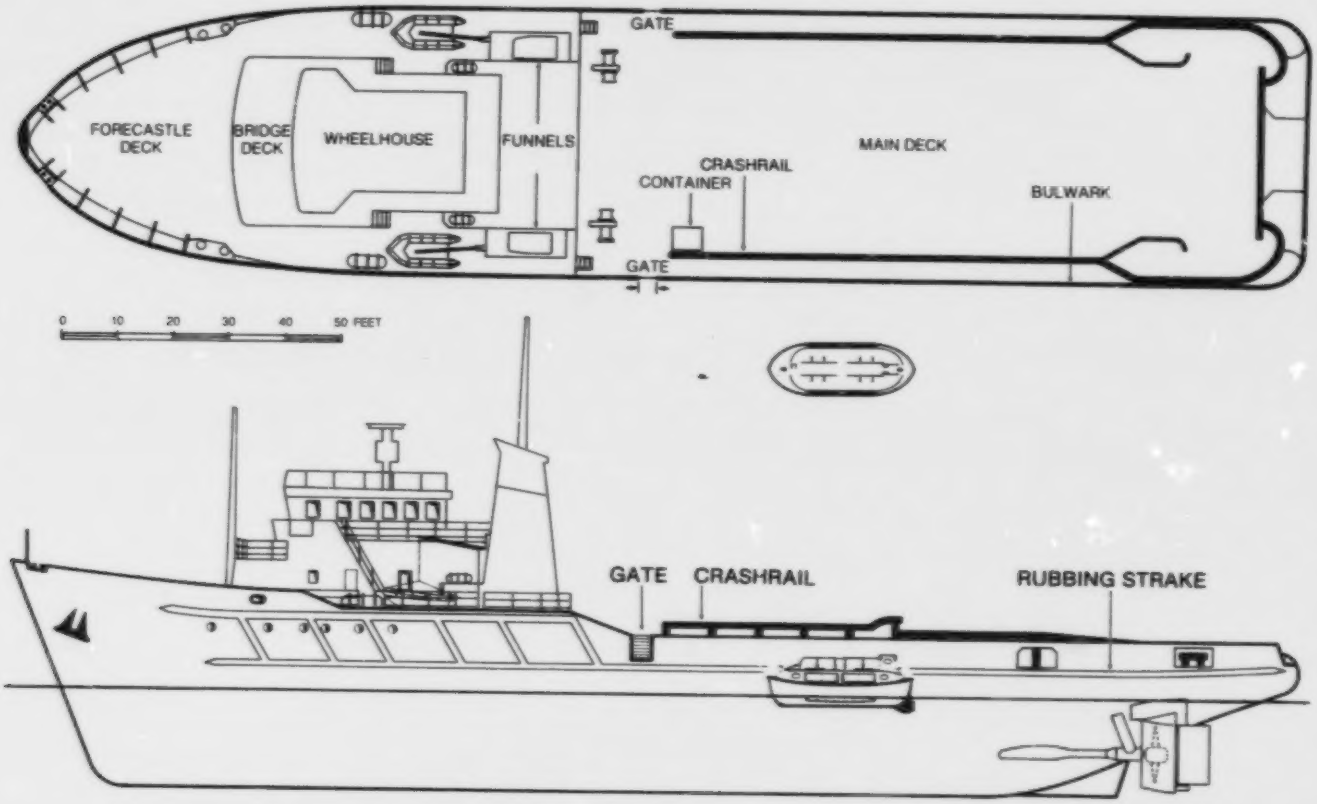
[1] A Chinook is a twin rotor helicopter similar in design to the SAR Labrador/Voyageur helicopters.



9.2 This is a plan and elevation view of the *Seaforth Highlander* and the Harding lifeboat in stillwater. On February 15, 1982, the severe sea conditions seriously hampered rescue attempts.

event of evacuation of a rig. It is only fair to state, however, that through circumstances beyond their control, Graham and Fraser and even the radio operator were laden throughout that period with duties and responsibilities which they were not qualified by training or experience to carry out.

The marine resources available under contract to Mobil were seven supply vessels. Three of them were on standby duty on the Hibernia Field; the other four were tied up in St. John's harbour. Supply vessels, however, are designed for carrying heavy goods and materials, for towing, and for anchor handling. Their wheelhouse is located on the top of a high superstructure near the bow of the ship. The working and cargo deck runs from this superstructure to the square stern of the ship and is fitted with solid bulwarks on both sides. There are no appropriate gates or openings in these bulwarks to facilitate rescue which, in any case, would be difficult because of the high freeboard that is up to eight feet when the ship is without cargo. Another complicating factor is the rubbing strake running along both sides of the ship, which not only lessened the possibility of rescuing someone from the stormy seas but which could possibly catch the gunwale of a lifeboat and capsize it. The configuration of the supply vessels also hampered rescue operations. It is difficult to hold the bow into the wind at minimum speed in heavy seas because of the high superstructure. The captain or mate cannot keep an eye on the oncoming seas and the rescue efforts taking place from the deck behind him. The only alternative is to manoeuvre the stern of the ship into the wind and waves. The wheelhouse has a window and a control console facing aft. This enables him to watch both the waves and the actions of the crew while manoeuvring the vessel. In this position, however, waves can break over the low unprotected stern and wash over those involved in the rescue attempt. None of the vessels had special rescue equipment, such as a crane with basket or net, suitable for rescue operations during a storm. In fact, they did not even have the meagre amount of rescue equipment required under the COGLA regulations.

COGLA required the presence of a "suitable" standby vessel but its regulations did not specify the type of vessel that would be suitable to rescue the entire crew of a drilling unit and to treat, if necessary, a large number of survivors suffering from hypothermia. The regulations also did not require adequate rescue equipment and training for the crews of these vessels to cope with an emergency of this magnitude. Mobil did not specify what was required of the vessels for rescue purposes nor did the companies providing the vessels question the fact that they were expected to fulfill a standby role although they did not have the necessary equipment. Reasonable foresight ought to have dictated that these vessels be appropriately designed, adequately equipped and properly manned with specially trained personnel for rescue operations.

The crew of the *Seaforth Highlander*, who, without safety lines and with the deck awash, strove valiantly to save the men in the lifeboat displayed courage in the best traditions of the sea. Neither they nor the crews of the other vessels had training in rescue operations and, in their efforts to find and rescue survivors more could not have been asked of them. The *Seaforth Highlander*, however, as the standby vessel assigned to the *Ocean Ranger*, had a special duty and responsibility towards that rig. And yet, when help was urgently required, she was some eight miles away. There are several factors that may mitigate in defence of her master, Captain Duncan, and there are other people who must bear some share of responsibility for the location of his ship. When Captain Duncan took command of the *Seaforth Highlander* on February 7, 1982, he had no instructions regarding the standby role of his vessel nor were there any instructions posted on board for this assignment. He understood that he was taking command of an anchor handling supply vessel and it was only upon his arrival at the Hibernia site that he discovered that his vessel and crew would have to fill the rescue role.

Captain Duncan testified that he was told while he was at sea by someone on the *Ocean Ranger* that he should stay, weather permitting, within two miles of the rig. This was the practice of the other masters and was commonly known and accepted within the industry. Duncan intended to raise the matter with his employers upon his return to port but, in the meantime, on the basis of that conversation, drew up standing orders for "the particular benefit of bridge watchkeeping personnel who have little or no degree of experience with subject concerned." These standing orders stated that the primary duty of the vessel is "to maintain standby status as ordered by the rig and to be ready in all respects to save life." They specified the maximum distance (weather permitting) from the rig to be two miles and the actions to be taken in the event of a major disaster at the drill site. In compiling his standing orders Captain Duncan drew upon his experience in the North Sea. There were no COGLA or Newfoundland Petroleum Directorate regulations to guide him nor instructions from his company or from Mobil. COGLA regulations simply state that the "person in charge of a standby craft . . . shall . . . maintain the craft within such distance from the drilling unit as is approved by the Chief."[2] Neither the Chief nor any other COGLA official, however, had issued or approved written instructions on standby distances. The responsibility in practice was left to the operator but Mobil had issued no written instructions on the matter. Duncan's company, through a representative of Seaforth Fednav, argued that there was no mention of a standby role in its contract with Mobil. This is, however, not satisfactory either as an excuse or as an explanation. The role of these supply vessels was well known in the industry. The

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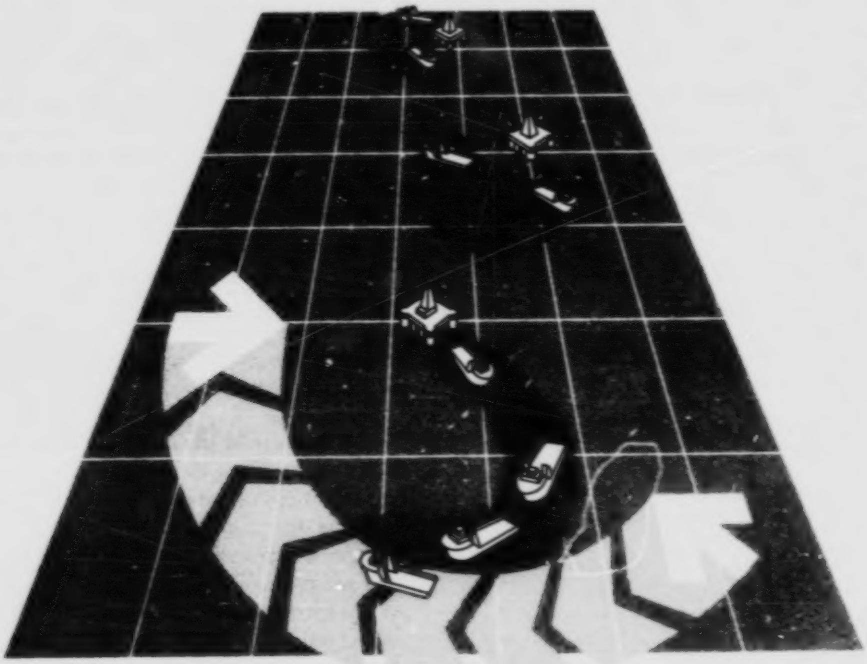
[2] *COGLA Drilling Regulations 1980* – Secton 142 (b). (The "Chief" was the Chief Conservation Officer or Administrator of COGLA under the *Oil and Gas Production and Conservation Act*.)



9.3 As the storm centre passed to the east of the Hibernia Field during the evening of February 14, the wind veered from the southeast to the west. The *Seaforth Highlander* proceeded into the wind and followed a course which led to a position approximately eight miles south of the *Ocean Ranger*. The *Boltentor* (centre) and the *Nordertor* (top) maintained dodging patterns upwind of their respective rigs.

company should have used the same initiative as Captain Duncan and issued the necessary standing orders for standby duties for its vessels under contract to oil companies exploring off Eastern Canada, or at least given verbal instructions to its captains.

The masters of the *Nordertor* and the *Boltentor*, both of whom had more experience on the Grand Banks than Captain Duncan, testified that it was their practice to move off from their assigned rig during stormy weather and to dodge upwind to a maximum of six miles and then downwind to within two miles. That is the course, according to their testimony, that they followed that night. In that way they were approximately within a half an hour of their respective rigs at all times. Captain Duncan's practice, according to the standing orders he drew up, was to dodge at a speed and on a course that "when conditions permit, the vessel presents bow or stern to heaviest swell to reduce rolling to a minimum." On the night of the loss he kept the bow of his vessel into the wind and maintained just enough power to maintain steerage and to keep control of the ship. He estimated, on the basis of the weather forecasts,that in this way he would initially move farther away from the rig but, as the wind swung around, his vessel would circle closer. Ironically, when he was called at 1:05 a.m. to come closer, his ship was at the farthest point away from the rig that the course that he adopted would take it. He testified that the waves that night were so tremendous that he was reluctant to turn his ship, fearing for the integrity of her structure and the safety of his crew. That reluctance was reinforced by his experience as captain of the *Seaforth Highlander* during a storm in the North Sea when the sea damaged her upper structure.

It is unquestionably the rule of the sea that the captain has the right to use his best judgement in protecting the safety of his ship and of her crew. That is his first and prime responsibility. But the captain of a standby vessel also has a direct responsibility for the crew of the rig. The course of action adopted that night by Captain Duncan was in marked contrast with those of Captain Davison of the *Boltentor* and Captain Allingham of the *Nordertor*. Taking into account, therefore, the actions of the other captains and the responsibility of a standby vessel, one is led to the conclusion that Captain Duncan ought to have been at closer standby. When, however, he heard the call to come to close standby, he did turn his ship and sped towards the rig with engines at full speed.

The three Sikorsky S-61 helicopters under contract with Mobil were used primarily to transport crew, light material and supplies. They were not equipped with hoists or any other equipment designed to lift men from a rig or from the sea, nor were the crews trained in rescue operations. They were alerted around 1:20 a.m. and the crews reached the airport around 2:15 a.m. but take-off was delayed by high winds. The first helicopter was airborne around 3:20 a.m. with ODECO rig superintendent, Counts, as the sole passenger. The second helicopter departed at 3:45 a.m. The weather conditions were highly questionable for flying: there was a low ceiling; it was overcast with mixed rain and snow; winds were gusting to 69 knots and there was the possibility of icing at the Hibernia site. There was no guarantee that the helicopters would be able to land on any rig for fuel, if it were required for the return trip but because of the nature of the emergency and the number of lives at stake the risk was taken and the flight made. The possibility existed that the pilots might be able to land on the rig to rescue the crew or otherwise participate in a rescue effort. In fact, they arrived too late to land on the *Ocean Ranger* but participated in the unsuccessful rescue attempt. Even if they had been alerted at around 1:00 a.m. when personnel on the *Ocean Ranger* first realized they were facing a serious situation, these helicopters would have been too late to rescue anyone. The courage, however, displayed by those who ventured out that night is highly commendable.

SAR RESPONSE

The SAR organization in Eastern Canada consists of the Rescue Co-ordination Centre (RCC) in Halifax which has the responsibility for co-ordinating search and rescue efforts for the entire eastern region of Canada and the Search and Rescue Emergency Centre (SAREC) at St. John's which has the responsibility for marine search and rescue within the Newfoundland area, unless that responsibility is taken over by RCC Halifax.

SAR uses a Time Line to depict the series of events marking the stages of a SAR incident. (The part of that Time Line relevant to the loss of the *Ocean Ranger* and its crew extends from the "incident occurs" to the "commencement of aid", marking the end of the response time of the SAR system.) The dedicated[3] SAR response system is started at the time RCC or SAREC is made aware that an incident has occurred. The amount of time which elapses before the response system starts depends upon the speed with which an incident is reported and the time consumed in relaying the crucial information that assistance is needed.

When an incident is reported, RCC or SAREC controllers either act immediately or obtain more information. Their actions are controlled in part by SAR procedures and by their own discretion and experience and are influenced by the nature, accuracy and completeness of the information that they have at their disposal. The controllers decide when and what SAR resources to task. The reaction of the SAR resource depends upon its standby status which, in the case of aircraft, may vary from 30 minutes to 2 hours depending upon time of day. The weather, the circumstances of the incident and other factors also influence the response time. Transit time depends on the distance between the base of the SAR resource and the location of the incident, the type of the resource, and the speed with which it can reach the

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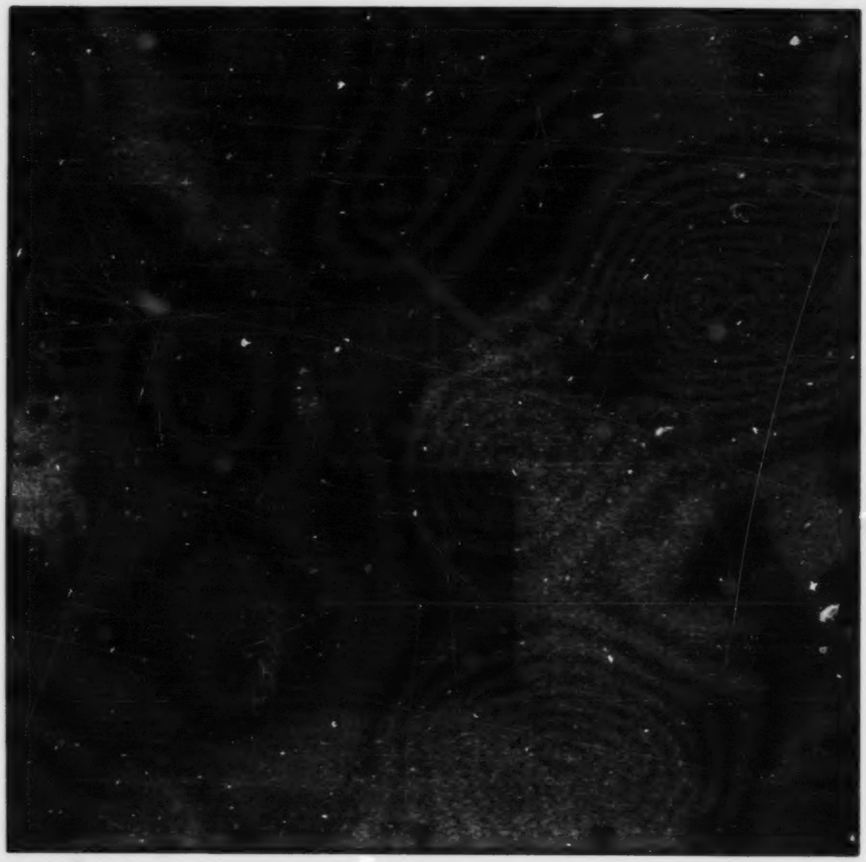
[3] "Dedicated" is a SAR term used to differentiate between primary and secondary SAR resources. Primary resources, or those dedicated specifically to search and rescue in the Halifax SAR region include aircraft stationed at Summerside, Prince Edward Island, and Gander, Newfoundland, and marine resources in Newfoundland and Nova Scotia. Secondary resources include air and marine resources of various government departments or ships of opportunity which could also be "tasked".

9.4 RCC Halifax is responsible for coordinating all Search and Rescue operations within an area of approximately 1.8 million square miles, of which 1.2 million square miles is over water.



scene. It is against this Time Line that the SAR response to the *Ocean Ranger* disaster must be judged.

SAREC was notified at 1:06 a.m. that the *Ocean Ranger* had problems and potentially needed help. This notification was repeated between 1:14 a.m. and 1:17 a.m. with the additional information that the rig had dispatched a Mayday. SAREC notified RCC Halifax at 1:21 a.m. that the *Ocean Ranger* had problems but made no reference to the Mayday. Information was included that there were three supply vessels in the area and that three or four commercial helicopters were being mobilized. RCC Halifax at the same time received a telephone call from RCC New York conveying the distress telex message sent from the *Ocean Ranger* by MARISAT at 1:09 a.m. and which RCC New York and RCC Halifax interpreted as a Mayday. At 1:31 a.m. RCC Halifax alerted the SAR 103 Rescue Unit at Gander. A fixed wing aircraft normally accompanies SAR helicopters to provide communications and search support, but the Buffalo at Summerside, Prince Edward Island, was not tasked by RCC Halifax until 2:24 a.m. It was not until 4:40 a.m. that the Aurora aircraft at Greenwood, Nova Scotia, was tasked and appointed "on-scene commander." RCC Halifax asked SAREC at 1:36 a.m. to have an All Ships Broadcast issued, but this was not issued until 2:04 a.m., 28 minutes later. Clearly, there were significant delays between each stage of the reporting and response process that require analysis and comment.

The summary of action taken by Search and Rescue authorities has been repeated for convenience and to facilitate a comparison with the SAR Time Line.

SAR TIME LINE
(OCEAN RANGER INCIDENT)

Incident Occurs	0100	Ocean Ranger alerts Mobil, St. John's
Agency Notified	0105	Mobil notifies SAREC St. John's
RCC Notified	0120	SAREC notifies RCC Halifax
SAR Retasked	0131	RCC Halifax tasks 103 Rescue Unit at Gander Nfld.
	0136	All Ships Broadcast Requested
	0146	RCC Halifax advised helicopters cannot take off
	0204	All Ship's Broadcast issued
	0224	RCC Halifax tasks Buffalo at Summerside P.E.I.
	0300	RCC Halifax tasks helicopter at Summerside
SAR Resource Departs	0353	Buffalo departs Summerside for St. John's
	0415	Helicopter departs Summerside for St. John's
	0440	RCC Halifax tasks Aurora at Greenwood, N.S.
	0815	Buffalo arrives St. John's
	0830 0850	Helicopters depart Gander for St. John's
	0714	Aurora departs Greenwood
	0735	Mobil advises SAREC that *Ocean Ranger* had disappeared
Commencement of Aid	0925	First SAR aircraft on site

Fifteen minutes passed from the time SAREC was initially alerted until they notified RCC Halifax and another ten minutes before RCC Halifax alerted Gander. Neither SAREC St. John's nor RCC Halifax had information readily available regarding the coordinates of the three rigs at Hibernia, the radio frequencies used by them, the dimensions of the *Ocean Ranger*, or the location, capacity and call signs of the commercial helicopters under contract to Mobil. Even though time is the single most critical factor in an emergency of this magnitude, SAR did not have a contingency plan which outlined the procedures to be followed in the event of a major marine disaster. There seemed to be a lack of preparedness at RCC and SAREC to meet the demands that would be made upon them when one did occur. There was no sense of urgency displayed by either organization in mustering resources and in responding to the request for help. Actions, even to sending out the All Ships Broadcast, were characterized by undue and unexplained delay. A mitigating factor may have been the false impression given that, with ships in the area and helicopters being mobilized, help was not urgently required. This circumstance, however, does not change the fact that, in spite of a clear warning that a major marine casualty was imminent, one hour was to pass before the Buffalo was tasked and five hours before it arrived at the St. John's airport. Likewise three hours went by before the Aurora was appointed an On-Scene Commander by RCC and more than eight hours before it arrived. In the meantime, co-ordination of the rescue effort was left to untrained Mobil personnel, and the captains of the three supply vessels, inexperienced in rescue operations, had to develop a search pattern without aid of air surveillance and without aid from RCC Halifax.

The air resources available to RCC Halifax to task in support of the *Ocean Ranger* came from 103 Rescue Unit at Gander, which had three Labrador/Voyageur helicopters; from 413 SAR Squadron at Summerside, P.E.I., which also had three Labrador/Voyageur helicopters and three Buffalos; and from Greenwood, N.S. which provided an Aurora.

To provide air response 24 hours per day, 7 days per week and 365 days per year, and to maintain the capability of having one helicopter ready to launch with a high degree of reliability, a SAR helicopter unit has to have a minimum of three helicopters and five crews[4]. If the squadron had only two helicopters, there would be no helicopter available for approximately 8% of the year, because of the random effect of helicopter downtime due to planned and unplanned maintenance (Appendix G, Item 6). If three are assigned, there will be no helicopter available for approximately 1% of the time. Unplanned maintenance can make the situation even worse; the Gander squadron, for example, had no helicopter ready to respond to a request for aid for a 63-hour period in March, 1982. The number of crews required to man three helicopters depends upon the length of the standby[5].

The Labrador/Voyageurs are twin turbine, tandem-rotor amphibious helicopters with a normal cruising speed of 115 knots and an operating radius of approximately 225 nautical miles. They carry a full complement of rescue equipment and normally a crew of five, consisting of pilot, co-pilot, two SAR technicians and a flight engineer. These helicopters were manufactured some twenty years ago and have undergone extensive renovations. They are no longer being produced and spare parts are therefore difficult to obtain. To maintain them to Department of National Defence standards requires a rigorous maintenance program involving long periods of time when a helicopter is not available for duty. The helicopters at Gander in February 1982 did not have radar, automatic flight control systems, hover coupler systems or VHF/FM marine band radios. Radar allows the pilot to fly below cloud cover at night because he can differentiate and locate high ground. The absence of radar would force the pilot to fly above the high ground possibly into clouds where rime icing may exist. An automatic flight control system and hover coupler system would aid considerably in rescue operations as they would allow the helicopter to hover in a fixed position close to the water without pilot assistance. The absence of VHF/FM marine radios prohibited the helicopters from communicating directly with vessels during a rescue attempt. The main deficiency of the Labrador/Voyageur, however, is its relatively short range and endurance for marine rescues offshore. There are also weather limitations because these helicopters are not permitted to fly when there is icing, present or forecast. The Labrador/Voyageurs are also limited for start up and shut down, by manufacturer's specifications, to steady winds of 52 knots. The presence or forecast of gusts will reduce that limitation to 30 knots when the gust spread reaches the allowable maximum of 15 knots.

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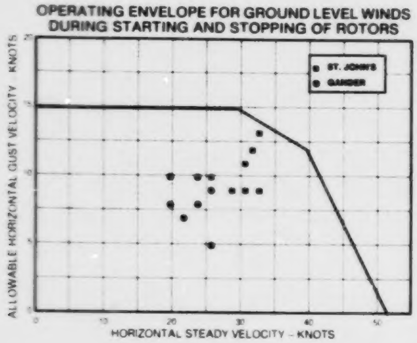
[4] This establishment will make possible the provision of a response at 30 minutes' notice during working hours and at two hours' notice during off-duty hours when at least one crew will be on call at home.

[5] For a 30-minute standby, eight hours per day every day of the year, six crews are required.

When RCC Halifax placed 103 Rescue Unit (Gander) on alert at 1:31 a.m. one helicopter was serviceable but later that morning, at 5:30 a.m. a second helicopter became available. Weather conditions, however, in the opinion of the aircraft commander, prohibited flying. Although there existed some ambiguity about wind conditions in Gander at that hour, a review of the forecast has shown that the winds at Gander were less severe than those at St. John's and at neither place did they exceed the limitations imposed upon the helicopter for start up. The limiting factor, according to the helicopter's operating manual, was that an area forecast indicated the possibility of rime icing in the clouds between Gander and St. John's. There is no method of verifying quickly whether rime icing in clouds is in fact occurring except by actually flying. To fly the direct route between Gander and St. John's, it would have been necessary for the pilot to enter the low cloud layer to avoid the high intervening ground and thus possibly encounter rime icing if it, in fact, were present in the clouds. The commanders of the helicopters decided not to take the risk. There was an alternate route along the Gander River to the coast and thence over water to St. John's beneath the cloud layer. But without radar and an automatic flight control

9.6 A SAR Labrador/Voyageur helicopter.



TIME	ST. JOHN'S				GANDER			
0130	33	gusting	to	42	26	gusting	to	35
0230	31	"	"	42	26	"	"	31
0330	33	"	"	46	24	"	"	34
0430	31	"	"	40	22	"	"	29
0530	26	"	"	36	24	"	"	32
0630	29	"	"	38	20	"	"	28
0730	32	"	"	44	20	"	"	30

9.7 A comparison of the actual wind velocities at Gander and St. John's shows that at neither place did they exceed the start-up limitations imposed on the Search and Rescue helicopters.

system, flying a helicopter in instrument conditions at low level would be, as one of the pilots observed, "just too risky."

The question of risk or safety as Major Fred Rehse, the commander of the SAR 103 Rescue Unit testified, ". . . is a relative thing. It is a very difficult practice and we leave it to the discretion of the aircraft commander to in fact decide whether he can do that job, that particular mission or not." He also testified that, "there is always a pressure to try and do the mission." When a major disaster is imminent and many lives are at stake the degree of risk to be run or parameter of safety to be observed becomes an even greater question. Conscious of this pressure when lives are at stake, the SAR pilot must make his own assessment of adverse weather reports, equipment limitations, the operating capabilities of his aircraft and the route to be flown. After weighing these factors against what he knows of the emergency confronting him, he must decide whether to leave immediately or wait for improved conditions. SAR 103 Rescue Unit reported at 1:46 a.m. that they would not be flying because of weather limitations. The two SAR helicopters eventually left Gander at 6:30 a.m. and 6:50 a.m. respectively, around first light, and reached St. John's airport at 7:17 a.m. and 7:30 a.m. where they refuelled before proceeding to Hibernia. At 3:00 a.m. RCC Halifax tasked a Voyageur helicopter at Summerside to proceed to St. John's where it arrived at 8:30 a.m. The Buffalo arrived there from Summerside at 6:15 a.m.

These delays precluded the possibility of the SAR aircraft participating in the rescue of the crew of the *Ocean Ranger*. They arrived too late. But they would still have been too late even if conditions had been ideal. For if the SAR helicopters had been based in St. John's, fully fueled and with the crews on 30-minute standby, when SAREC was first informed between 1:14 a.m. and 1:17 a.m. of the emergency, the earliest time of departure, even if the effects of the wind are ignored, would have been 1:45 a.m. When they eventually flew to the site of the *Ocean Ranger*, the flying time was 70 minutes. The earliest time of arrival at the site would, therefore, have been around 2:55 a.m. The rig was evacuated between 1:30 a.m., when the men went to the lifeboats, and, possibly, 2:00 a.m. The lifeboat alongside the *Seaforth Highlander* capsized at 2:38 a.m. and its occupants, lacking survival suits, appeared lifeless within minutes of the capsize. The helicopter would in fact have been delayed in getting started up under the weather conditions that night, as were the Universal Helicopters.

The vessels of the Canadian Coast Guard closest to Hibernia were in port in St. John's. Their distance from the site precluded any possibility of aid to the *Ocean Ranger*. Even if there had been more time, however, it appears doubtful that these vessels could have played an active part in that night's rescue. Their crews had been granted shore leave and were not mustered to the ships until much later in the morning of February 15. These vessels were not, however, dedicated SAR resources and were not, therefore, primarily concerned with nor responsible for maintaining a standby/rescue role. The dedicated SAR vessels were the *Jackman*, which was at Burgeo, and the *Grenfell* located in Notre Dame Bay.

COMMUNICATIONS AND RESPONSE TIMES

TIME	FROM	TO	MESSAGE
FEBRUARY 15			
0100	*Ocean Ranger* J. Jacobsen	St. John's Merv Graham	*Ocean Ranger* listing; cause unknown requests Coast Guard alert; 84 men on board
0105	*Ocean Ranger*	*Seaforth Highlander*	Called to close standby; listing badly; countermeasures ineffective
0106	Mobil St. John's Merv Graham	SAREC St. John's	*Ocean Ranger* listing to bow; cause unknown; 84 men on board; local weather conditions; supply boats to be dispatched; Universal Helicopters to be alerted no direct assistance requested from SAREC
0109	*Ocean Ranger*	MARISAT Connecticut	Distress Telex received and routed to RCC New York;
	Connecticut MARISAT Operator	RCC New York	Routed distress message
0110	*Ocean Ranger* Ken Blackmore	Mobil St. John's Rick Flynn	Requests Mayday for *Ocean Ranger*
0111 Approx.	*Ocean Ranger* Jack Jacobsen	*SEDCO 706* Keith Senkoe	Advises assistance needed; requests Mayday relays; request for helicopters and supply boats of *Zapata Ugland* and *SEDCO 706* to assist in evacuation
0112	Connecticut MARISAT Operator	RCC New York	Distress message received
0112	*Ocean Ranger*	RCC New York	Distress telex giving location, weather conditions; severe list 10-15 degrees and increasing; requesting assistance ASAP
0114- 0117	Mobil St. John's Rick Flynn	SAREC St. John's	*Ocean Ranger* listing; evacuation appeared necessary; *Ocean Ranger* attempted Mayday and requested Mayday relay via the *SEDCO 706*; Mobil helicopters alerted; Flynn patches SAREC into *Ocean Ranger* transmissions
	Site via Mobil base	SAREC St. John's	SAREC overheard conversation between *Ocean Ranger* Drilling Foreman/Mobil Operator and *SEDCO 706* Drilling Foreman requesting assistance from other supply boats; winds from the west gusting to 80 mph; three supply boats in the area; helicopters alerted
0120	Mobil St. John's Merv Graham	*SEDCO 706* R. Fraser	Appoints Fraser as On-Site Coordinator; advises that Mobil's helicopters alerted; requests other supply boats be dispatched; monitor all radio communication and report to shore

0121	*SEDCO 706*	*Boltentor*	Directed to proceed to *Ocean Ranger* and assist as required
	SAREC St. John's	RCC Halifax	Advised of *Ocean Ranger's* distress; failed to indicate *Ocean Ranger* had attempted Mayday and had requested that *SEDCO 706* transmit Mayday relay
	RCC New York	RCC Halifax	Transmitted info contained in distress message
	RCC Halifax	SAREC St. John's	Acknowledges receipt of information from RCC New York
0122	*SEDCO 706*	*Zapata Ugland*	Directed Nordertor to proceed to *Ocean Ranger* site and assist as required
0130	*Ocean Ranger* K. Blackmore	Mobil St. John's Rick Flynn	Advises that the crew were going to the lifeboat stations; Both Mobil base and *SEDCO 706* acknowledge message
	Mobil St. John's Rick Flynn	SAREC St. John's	Advises that the crew had gone to the lifeboat stations; *SEDCO 706* sending Mayday relay; Mobil's helicopters alerted; all supply boats directed to proceed to *Ocean Ranger* and assist as required
	RCC New York		Telex connection with the *Ocean Ranger* broken; attempts to regain connection unsuccessful
	SEDCO 706	*Boltentor & Nordertor*	All speed to *Ocean Ranger*
0131	SAREC St. John's	RCC Halifax	*Ocean Ranger* crew to lifeboat stations
0131- 0136	RCC Halifax	103 Rescue Unit Gander Capt. Preus	Advised of emergency on *Ocean Ranger*; requested to muster helicopter crew for rescue mission
	RCC Halifax	Maritime Command Operations (MARCOM)	Determine marine and air resources under control of Dept. of National Defence in position to render assistance; Aurora at CFB Greenwood available later in a.m.
	RCC Halifax	RCC New York	Request for surface picture (SURPIC) vessels within 100 mile radius of *Ocean Ranger*
	RCC Halifax	SAREC St. John's	Request to issue All Ship's Broadcast
0146	103 Rescue Unit Gander	RCC Halifax	Advises that crews alerted and proceeding to the airport; advises that departure delayed until weather improves
0148	SAREC St. John's	Coast Guard (VON) Marine Radio Stn St. John's	Telex request to issue All Ship's Broadcast
0155	*Seaforth Highlander*	*SEDCO 706*	Three miles from *Ocean Ranger*
0203	Coast Guard (VON) Marine Radio Stn St. John's		Receipt of telex
0204	Coast Guard (VON) Marine Radio Stn St. John's		All Ship's Broadcast issued

0211	*Seaforth Highlander*	*SEDCO 706*	Made visual contact with *Ocean Ranger* and reported seeing life jacket lights in the water
0214	*Seaforth Highlander*	*SEDCO 706*	Sighted distress flare from lifeboat
0215	St. John's		Universal Helicopters crew arrived at airport
0221	*Seaforth Highlander*	*SEDCO 706*	Sighted second distress flare and was proceeding toward lifeboat
0224	RCC Halifax	413 Rescue Unit Summerside, PEI	Aircraft required to provide communication & air support; Buffalo aircraft & Voyageur helicopters tasked
0232	*Seaforth Highlander*	*SEDCO 706*	Reported lifeboat alongside
0234	RCC New York	RCC Halifax	Supplied surface picture (SURPIC)
0238	*Seaforth Highlander*	*SEDCO 706*	Lifeboat capsized
0245	*Boltentor*		Arrives at *Ocean Ranger* site
	Boltentor	*SEDCO 706*	Advises rig still upright; few lights visible
	SEDCO 706	*Boltentor*	Determine if helicopter could land on the rig; Reply affirmative
0255	*Seaforth Highlander*	*Boltentor*	Requests assistance in recovering the lifeboat
0300	RCC Halifax	413 Rescue Unit Summerside, PEI	Tasked a Voyageur to proceed to St. John's
0300 Approx.	*Nordertor*		Capt. Allingham noticed that radar contact was lost with *Ocean Ranger*
0315 Approx.	*Nordertor*	*Boltentor* *Seaforth Highlander*	Capt. Allingham checked to see if other vessels had radar contact with *Ocean Ranger*, they replied no
0322	St. John's		First Mobil helicopter departs St. John's
0338	*Nordertor*	*SEDCO 706*	Reported that the *Ocean Ranger* disappeared from the radar screen
	SEDCO 706	Mobil St. John's Merv Graham	Relay that radar contact lost with *Ocean Ranger*; agreed that Mobil would advise SAREC
0340	*Nordertor*		Arrives at site
	SEDCO 706	Mobil St. John's	Three supply boats would coordinate search efforts
0353	413 Rescue Unit Summerside, PEI	RCC Halifax	Buffalo aircraft departs PEI
0408	*SEDCO 706*	All Supply Vessels	Advised to cease direct transmission to shore and told to relay all information to *SEDCO 706*
0415	413 Rescue Unit Summerside, PEI	RCC Halifax	Voyageur departed for St. John's
0435	Universal Helicopter		Arrives at site
0440	RCC Halifax	CFB Greenwood	Additional air support tasked; Aurora aircraft stationed at Greenwood, N.S. appointed on-scene commander

0500	*Selfoss*	Coast Guard (VON) Marine Radio Stn St. John's	The *Selfoss* was the first vessel to respond to All Ships Broadcast
0600	Universal Helicopter		Airborne for return trip to St. John's
0615	SAREC St. John's	RCC Halifax	First Search and Rescue helicopter from Summerside arrives St. John's
0630	103 Rescue Unit	RCC Halifax	SAR helicopter leaves Gander for St. John's
0650	103 Rescue Unit	RCC Halifax	Second SAR helicopter leaves Gander for St. John's
0714	CFB Greenwood	RCC Halifax	Aurora departs for site
0730	SAREC St. John's	RCC Halifax	SAR helicopters from Gander arrive St. John's to refuel and receive updated information on rescue effort
0735	Mobil St. John's	SAREC St. John's	Advised *Ocean Ranger* had disappeared
0830	SAREC St. John's	RCC Halifax	Two SAR helicopters depart for site
0835			Two Universal helicopters return to St. John's from *Ocean Ranger* site
0935	SAR aircraft	SAREC St. John's	SAR aircraft arrive at site and begin co-ordinated search
0946	RCC Halifax	SAREC St. John's	Instructions to task CCGS *Bartlett*
1042	RCC Halifax	SAREC St. John's	Instructions to task the *Gadus Atlantica* which was 119 miles from site
1043	RCC Halifax	SAREC St. John's	CCGS *Bartlett* released CCGS *Sir Humphrey Gilbert* tasked
1139	RCC Halifax	SAREC St. John's	Tasked the *Java Seal*
1139	SAREC St. John's	RCC Halifax	CCGS *Bartlett* was retasked to replace the *Gilbert*

FEBRUARY 16

0908	RCC Halifax	SAREC St. John's	CCGS *Bartlett* was retasked to replace the *Gilbert*

FEBRUARY 17

1630	RCC Halifax	SAR Ottawa	Formal request that search effort be reduced

FEBRUARY 19

2310	SAR Ottawa	RCC Halifax	Search for survivors discontinued although vessels in the area maintained watch

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CONCLUSIONS AND RECOMMENDATIONS

CHAPTER TEN CONCLUSIONS AND RECOMMENDATIONS

Part I of the Terms of Reference of the Royal Commission directs it to inquire into, report upon, and make recommendations with respect to matters directly relating to the *Ocean Ranger* and its loss. The preceding nine chapters contain in considerable detail the results of this inquiry. From the testimony and other evidence, conclusions have been reached on the cause of the loss of the rig and its crew and recommendations have been developed which address a number of the issues raised during the inquiry. This final chapter contains the conclusions and recommendations related to each of the Part I Terms of Reference. Since the evidence heard was generally restricted to the *Ocean Ranger* and was not intended to provide information and opinions on an industry-wide basis, recommendations are being deferred until the final report in cases where additional information is thought to be necessary. Part II of the Terms of Reference goes beyond the loss of the *Ocean Ranger* to consider safety aspects of exploratory drilling operations off Eastern Canada. A much wider range of evidence and opinion is, accordingly, being sought before conclusions are reached and recommendations made with respect to these operations.

"1. Inquire into and report upon the loss of all members of the crew of the semi-submersible self-propelled drill rig *Ocean Ranger*, and of the *Ocean Ranger*, on or about the 15th day of February, 1982, on the Continental Shelf off Newfoundland and Labrador, the reasons and causes therefor . . ."

The loss of the *Ocean Ranger* was caused by a chain of events which resulted from a coincidence of severe storm conditions, design inadequacy and lack of knowledgeable human intervention. Once the design decision was made to locate the ballast control room in the third starboard column, 28 feet above mean water level at operating draft, the room and its equipment should have been protected from all reasonably foreseeable environmental forces. The design weaknesses included a failure to specify portlights of adequate strength, and to provide a ballast control panel with components that were suitable for operation in an environment where there was a risk of exposure to sea water. The ballast control system was unnecessarily complicated, and the interconnection between the electrical circuits for the control and monitoring aspects of the system made the ballast control console susceptible to common faults and the presentation of confusing information. The lack of a remote system for reading the draft of the rig made it necessary for the deadlights to be open as a routine matter in order to view the draft marks. This weakness in design led to the development of the dangerous habit of leaving the deadlights open at all times.

Despite the failure of the portlight and the malfunctioning of the ballast control panel, the loss could have been prevented by knowledgeable intervention on the part of the crew. Indeed, had the crew only closed the deadlights, shut off the electrical and air supplies to the panel, cleaned up the water and glass and then retired for the evening, the *Ocean Ranger* and its crew would have survived the storm that night.

The failure of the crew to adopt and follow a proper and prudent operational practice – closing the deadlights in storm conditions – allowed the first link in the chain of events to be forged. In attempting to remedy the problems caused by the ingress of water into the ballast control room, the crew, because of a lack of understanding of the ballast system as a whole, reactivated the panel as part of the maintenance process and unintentionally allowed water to enter the port pontoon. Then, in attempting to remedy the port forward list of the rig by pumping out forward tanks, they failed to realize the possibility that one or more valves to aft ballast tanks were open, and actually increased the forward list by unintentionally pumping out of the aft tanks. The crew did not understand the proper function of the manual control rods and inserted them in a mistaken attempt to close valves. This resulted in the opening of up to 15 ballast tank valves, which allowed ballast water to gravitate forward and accelerated the rate of forward trim.

Another weakness in design allowed water to flood into the chain lockers which had no weather-tight covers, and no permanently installed means of pumping out water. Flooding into the upper deck spaces through damage to the accommodation area and to the ventilators leading to the sack storage area also contributed to the capsize of the rig.

All 84 members of the crew lost their lives in the casualty. The cause of death of those bodies recovered was drowning while in a hypothermic condition. Once abandonment of the rig became necessary, it was of paramount importance that the crew be able to survive until help arrived. That they were not able to do so was due firstly to the absence of an evacuation system which could provide reasonable assurance of a safe departure from the rig under the circumstances that existed. One of the stern lifeboats did miraculously get clear of the rig although it was severely damaged during launching to the point where it could no longer be regarded as safe. The other stern lifeboat is believed to have been launched but to have been lost in the process. The second major factor contributing to the loss of the crew was a lack of "survival suits". These suits, which were commercially available at the time of the loss, would, if provided and properly worn, have appreciably lengthened the time of survival. Had every man been properly protected by a survival suit, there is a real probability that some of them would have survived.

"1. (a) . . . to inquire into, report upon and make recommendations in respect of the design, construction and stability of the *Ocean Ranger* and its suitability to conduct marine and drilling operations on the Continental Shelf off Newfoundland and Labrador;"

There were features of the design of the *Ocean Ranger* that contributed to its loss – the location of the ballast control room, the inadequate strength of the portlights, the lack of protection of the ballast control console and the vulnerability of the chain lockers to flooding. There were also other features that are cause for concern – the diminishing capability of the pumping system to pump water from the forward tanks as the rig inclined by the bow and the location of the sensor tubes for the tank level gauges.

Apart from the failure of the portlight in the ballast control room, there is no evidence to indicate that the *Ocean Ranger* was other than structurally sound. The dive surveys revealed no evidence of primary structural failure, and the damage which was observed was the result of the capsize rather than a contributor to it. Indeed, that not more damage was discovered is testimony to the structural strength of the rig.

There is no evidence to indicate that any loss of intact stability contributed either to the initial trim or to the eventual capsize of the rig. According to the morning report for February 14 and to the working copy of the stability report recovered from the ballast control room during the dive, the *Ocean Ranger* had on February 14, 1982, a relatively light deckload and a positive metacentric height well in excess of the minimum requirements. With the additional stability enhancement provided by the moorings, the rig had an even greater effective metacentric height and more than sufficient stability to survive the storm conditions. Nevertheless throughout the hearings a number of matters relating to stability were raised and require comment.

It is a common phenomenon that drilling units[1] are susceptible over the years to weight growth that is unrecorded. This is a function of additional weight not being recorded and of errors in estimating the weights that were recorded. Annual unrecorded weight growth has been estimated to be 20 tons or more. This growth can have an adverse effect on the stability of a rig, particularly since the additional weight would usually be above the vertical centre of gravity (VCG) of the rig and would have the undesirable consequence of raising the VCG. If the draft marks on the rig cannot be measured with precision, and in the absence of periodic dead weight checks or a reinclining test, this weight growth would accumulate undetected.

The process by which the stability of a semisubmersible is reviewed during the design and classification process includes the determination of a downflooding angle and calculation of righting and heeling moments up to this angle. If up to this angle the ratio of righting energy to heeling energy in stipulated wind conditions satisfies classification requirements, the unit is considered to meet the intact stability requirements. On the *Ocean Ranger* the downflooding angle was considered to be that angle at which the chain lockers would commence to flood in still water and no account was taken of waves reaching the chain lockers before the downflooding angle was reached by the rig. The model tests confirmed that, in storm conditions, flooding of the chain lockers commenced long before the downflooding angle was reached. In the absence of weather proofing of the downflooding opening, the use of static conditions to determine the downflooding angle appears to be unrealistic.

The *Ocean Ranger* capsized after a loss of stability caused by gravitation and the ingress of water into the forward ballast tanks and by flooding of the chain lockers and upper hull. It appears that an assessment of damage stability involving the flooding of only one compartment is too restrictive, and that consideration should be given to revising the criteria. Where stability calculations assume, as in the case of the *Ocean Ranger*, the integrity and buoyancy of the upper hull structure, that structure must be watertight for the necessary distance from the periphery. The flooding of the sack storage area and of the accommodation area caused a loss of that buoyancy and precipitated the capsize of the *Ocean Ranger*.

The suitability of a rig to conduct marine and drilling operations on the continental shelf off Newfoundland is a function of many variables including the design and structural arrangement of the rig and its possible deterioration during its lifetime. The design weaknesses that contributed to its loss have been outlined above. They indicate that sooner or later an occurrence of that nature was probable and therefore considerably reduced the suitability of the *Ocean Ranger* for drilling operations on the continental shelf off Newfoundland. Knowledgeable human intervention, however, could have offset these design inadequacies and prevented the disaster. There is no evidence to suggest that the condition of the *Ocean Ranger* had deteriorated during its lifetime or that it was not adequately maintained. It is recommended:

> 1. That all drilling units be subject to an immediate review of structural openings leading to areas containing critical equipment affecting the stability and safety of the rig and that this review include an assessment of potential environmental forces on these openings, and of the strength of the material used to cover them. That, if the strength of the material is deemed not to provide an adequate safety margin, it be reinforced or removed and replaced with material of appropriate strength.

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[1] Unless evident otherwise from the context, the words "drilling unit" when used in this chapter refer to mobile offshore drilling units of the semisubmersible type operating or proposed for operation off Eastern Canada.

2. That all drilling units be required to have or to install, over the openings referred to above, covers that can be quickly and easily secured in the event of adverse weather forecasts. That each drilling unit be required to establish and enforce operating procedures that ensure the closing and securing of these covers when weather forecasts or actual conditions exceed established criteria.

3. That all equipment critical to the stability and safety of the rig be subject to a systems analysis which includes an analysis of the susceptibility of the equipment to damage and a review of the adequacy of the backup system, if any, and that, where required, appropriate measures be taken to protect that equipment from reasonably foreseeable risks.

4. That if flooding one or more of the chain lockers adversely affects the stability of the rig, they be equipped with flooding alarms and be adequately weather proofed and fitted with effective means of dewatering them.

5. That the system of pumping ballast water on drilling units be capable of pumping at an adequate flow rate to restore the rig to level attitude when the rig is inclined up to and including the static downflooding angle or the angle reached in the "worst case" damage stability situation, whichever angle is the greater.

6. That sensor tubes for tank soundings be located to permit maximum possible accuracy of readings when the rig is in other than a level attitude.

7. That conversion tables be provided for accurate assessment of tank contents when the rig is in other than a level attitude.

8. That sea chest valves be capable of being shut manually from a position on the rig which is above the weather deck.

9. That all drilling units be equipped with remote draft sensing and reading devices.

10. That all drilling units be equipped with recording gauges that provide accurate determination of maximum and minimum anchor tensions and produce a permanent record of all anchor tensions.

11. That each drilling unit be subject to a quadrennial deadweight check and weight audit carried out under the supervision of the regulatory authority or its authorized agent.

12. That the use of static downflooding angles for calculation of a righting/heeling energy ratio in the moment balance diagram be discontinued except where the point of downflooding is adequately weather proofed. That in the absence of weather proofing at the point of downflooding, a dynamic angle be calculated based upon deck flooding in design wave conditions and, where appropriate, on model tests and computer simulations.

"1. (b) . . . inspection, inspection procedures, licensing, classification and certification pertaining to the conduct of marine drilling operations by the *Ocean Ranger* on the Continental Shelf off Newfoundland and Labrador;"

The Royal Commission heard considerable evidence on the rules, standards, regulations and enforcement procedures used by various agencies which affected the *Ocean Ranger* and its crew. The evidence revealed deficiencies in the manner in which the marine operations of the *Ocean Ranger* were controlled by the regulatory agencies. The regulations which governed the industrial operation were adequate and through bi-weekly inspections were adequately enforced. Canada Oil and Gas Lands Administration (COGLA) and the Newfoundland and Labrador Petroleum Directorate (the Petroleum Directorate), however, relied upon the certificates issued by the American Bureau of Shipping (ABS) and the U.S. Coast Guard to attest to the safety of the marine operations of the rig. When the *Ocean Ranger* arrived on the Grand Banks, Canada had no standards of its own to assess the rig. Consequently

Canadian authorities accepted the ABS classification of the rig and its approval of the *Booklet of Operating Conditions* and did not conduct their own assessment of the rig and its operating procedures. Officials of COGLA and the Petroleum Directorate stated in evidence that they did not give priority to the safety of the marine operations and assumed that the certificates of the Flag State and the approval of the classification society provided the necessary assurance.

The regulations and guidelines of the Province of Newfoundland did not address the marine operations of the rig. Since there were general COGLA regulations in this area, the Petroleum Directorate relied upon COGLA and COGLA inspectors to enforce them. COGLA, however, did not enforce its regulations because they overlapped with regulations that were the traditional responsibility of the Flag State and with the rules of the classification societies. COGLA and the Petroleum Directorate acted on the incorrect assumption that ODECO would comply with the requirements of the 1979 *Certificate of Inspection*, issued by the U.S. Coast Guard, and with the *Booklet of Operating Conditions* approved by ABS and the U.S. Coast Guard. The U.S. Coast Guard did not monitor or follow up the conditions attached to the *Certificate of Inspection* which required modifications to the lifesaving equipment on the rig. Neither did they monitor the marine crew requirements set out in the *Certificate* or maintain any check on its expiry date. According to these requirements, the *Ocean Ranger* was undermanned by a minimum of three certificated lifeboatmen and two able-bodied seamen. The *Certificate of Inspection* and the *Cargo Ship Safety Equipment Certificate* issued by the U.S. Coast Guard to the *Ocean Ranger* had expired on December 27, 1981. It is recommended:

> **13.** That the continuing validity of a Drilling Program Approval or Authority to Drill a Well be conditional upon the validity of all certificates applicable to the drilling unit as detailed in the April 1984 *COGLA Guidelines and Procedures*, Section 1, Appendix B.

An argument was advanced by the counsel for the Government of Canada that Canada did not have legal jurisdiction to enforce marine safety regulations on foreign registered MODUs operating on its continental shelf outside the 12-mile limit. Foreign registered MODUs like the *Ocean Ranger*, he contended, are subject to regulation by the country of registry and are presently not subject to the *Canada Shipping Act*. Although this argument is legally correct, foreign registered MODUs can and should be regulated by Canada under the drilling permits issued to the operators. In light of the limited enforcement procedures used by the U.S. Coast Guard in regulating the *Ocean Ranger*, Canada should enforce its own standards.

Subsequent to the loss of the *Ocean Ranger*, Canadian regulatory agencies have changed their regulations. In July 1982, the Petroleum Directorate promulgated regulations governing the design, construction and stability of MODUs operating off Newfoundland. After a MODU is assessed by an independent third party for compliance with the Provincial regulations, a *Certificate of Fitness* is issued that is valid for up to 5 years.

Changes in the federal regulatory system since the loss of the *Ocean Ranger* are not clear. In 1984 the Ship Safety Branch of the Canadian Coast Guard published *Interim Standards Respecting Mobile Offshore Drilling Units*, the provisions of which are based on the International Maritime Organization's *Code for the Construction and Equipment of Mobile Offshore Drilling Units*.

Although in the form of regulations the *Interim Standards* have not been enacted under the provisions of the *Canada Shipping Act* and do not have the force of law. The authority given for their adoption is Section 370(2)a of the *Act* which relates to decisions of the Board of Steamship Inspection. Section 370(3) of the *Act* is the section which authorizes the making of rules and regulations and provides, *inter alia*, that, after they are approved by the Governor-in-Council, they are in force and have effect as if they had been included in the *Act*. The *Interim Standards* have not received the approval of the Governor-in-Council.

Even if the *Interim Standards* had the force of law, they are applicable primarily to new construction and regulate existing rigs only "to the extent considered reasonable and practicable" by the Board of Steamship Inspection. Accordingly there is no assurance that any of the standards, a number of which are very desirable, will be applied to existing rigs. It would have been preferable to set, by regulation, minimum standards for all units, and, if desirable, more stringent standards applicable only to new construction.

In the preamble to the *Interim Standards* it is proposed that all foreign registered drilling units comply to the same extent as if they were Canadian registered units. The Royal Commission is in full agreement with this requirement but is nevertheless concerned that the existing regulatory system may not be adequate to accomplish that purpose. COGLA's 1984 guidelines require detailed construction drawings to be submitted to the Canadian Coast Guard (CCG) "to ensure compliance with CCG standards for mobile offshore drilling units." They also provide that for a foreign flag drilling unit, compliance with CCG standards involves the submission of the information detailed in Appendix B of the guidelines, but that appendix lists information that is unsupported by the COGLA regulation which it purports to interpret. Even if compliance of foreign flag rigs with the Canadian Coast Guard's *Interim Standards* could be enforced, the standards would be unknown for they would only be those termed reasonable and practicable by the Board of Steamship Inspection.

Accordingly, although some of the recommendations which have been made already and some which follow may appear to duplicate the provisions of the *Interim Standards*, they are nevertheless made to emphasize the view that the requirements should be applicable to all drilling units and that they should be in such form that they can be unquestionably enforced. It is recommended:

> **14.** That Canada adopt standards for the design, construction and stability of offshore drilling units and that no drilling unit be permitted to operate unless it meets those standards as evidenced by a *Certificate of Fitness* issued by or on behalf of the regulatory authority.

Not only should there be Canadian standards for the design, construction and stability of drilling units but there should be operational standards as well. The operation of ships, as well as their design, construction and stability, is subject to regulation under the *Canada Shipping Act*. There is no reason why drilling units should not also be regulated. Although provision is made in the proposed *Interim Standards* for some operational requirements for drilling units the provisions are not the comprehensive operational standards which should be specifically developed for application to units operating off Eastern Canada.

It is not suggested that all regulations under the *Canada Shipping Act* be applied to drilling units on the grounds that they are ships within the meaning of the *Act*. What is suggested is that recognition be given to the fact that these units, even though they may not be properly termed "ships", are structures of a special class which carry out specialized operations in a manner significantly different from that of conventional ships. Recognition of that fact should give rise to operational standards specifically designed for drilling units, which, if prepared in consultation with the offshore industry, should be both realistic and acceptable.

The changes effected by COGLA since 1982 have been primarily enforced by way of "guidelines" to the regulations. The regulations have not changed. The use of guidelines as a means of enforcing standards merely represents an interpretation of regulatory requirements. Because these guidelines are subject to interpretation by industry and government, they may not be applied in a consistent manner to all operators. The effectiveness of this "guideline" system of regulating the industry will be examined in more detail in the final report of the Royal Commission. It is recommended:

> 15. That whether regulations or guidelines are used to express the wishes of the regulatory authority, there be consultation with industry to ensure proper administration and consistent enforcement.
>
> 16. That Canada adopt general operational standards for drilling units.

The proposed *Interim Standards* also provide for the submission and approval of an operating manual containing guidance for the safe operation of the unit under normal and emergency conditions. That provision should be adopted but the operating manual and the book of emergency procedures should be combined and should clearly state whether the procedures intended to be taken are mandatory or simply guidelines. Furthermore it should provide that where mandatory requirements are not carried out the failure to do so should be logged and a written report of the fact be made to the appropriate regulatory authority. It is recommended:

> 17. That in addition to the general and type-specific operational standards there also be platform- or rig- specific operating standards or procedures. That these standards be set out in a manual of operating conditions and emergency procedures for each unit and be subject to the approval of the regulatory authority. That the conditions or procedures which are mandatory be clearly designated and provision made for logging and reporting to the regulatory authority any noncompliance with mandatory provisions.

In the event of a marine casualty involving a Canadian registered drilling unit the organization or person having any information, document or record relating to the unit is obliged to make it available to Federal Marine Casualty Investigators if it should be required in the course of an investigation under the *Canada Shipping Act*. There is no corresponding requirement in the event of a casualty involving a foreign registered rig. The fact that noncompliance by the owner of the unit could result in the loss of the operator's permit does not ensure that this information is made available to Canadian investigators.

Since it is Canadian policy to have, to the extent that it is feasible, its citizens man foreign registered rigs operating under Canadian permits, it should afford to Canadian citizens the same benefits arising from Marine Casualty Investigations as are enjoyed by those who work on Canadian registered rigs. Just as the proposed *Interim Standards* require that foreign registered drilling units comply with these standards as if they were Canadian registered, so too should all units be required to comply with Canadian requirements in the case of Marine Casualty Investigations. It is recommended:

> 18. That no drilling unit be permitted to drill unless and until the owner or other appropriate person provides the appropriate Canadian authority with an irrevocable authorization directing the builder, designer, classification society and the state of the rig's registry to provide the information and documentation with respect to the rig as may be requested.
>
> 19. That no drilling unit be permitted to drill unless and until the owner or other appropriate person provides the appropriate Canadian authority with an irrevocable undertaking to comply in all respects with the requests, demands and subpoenas of any Canadian authorized marine casualty investigation and that to ensure compliance with that undertak-

> ing the owner or other appropriate person be required to post a bond or other security in an amount or type satisfactory to the Canadian authority.

Even with the stringent standards and thorough inspections contemplated by the proposed ***Interim Standards***, there may still exist on drilling units features that may be inherently unsafe or at least undesirable. On the ***Ocean Ranger***, for example, the location of the fairleads and anchor cables above the surface of the water, the location of the ballast control room, the lightly designed and dangerously exposed portlights in the ballast control room, the unprotected openings to the chain lockers, and the use of throw overboard inflatable life rafts equipped with painters which barely reached the surface of the water, were all features which did not have to exist.

Before they commence drilling operations off Eastern Canada and periodically thereafter all drilling units should be subjected to an analysis of their critical systems, the methods of operating those systems and their interrelationship. If the appropriate regulatory authority does not have the expertise to conduct this analysis, it should retain the necessary experts to act on its behalf. In this respect it would be inappropriate to retain the organizations or persons who had previously been involved in the design, construction or classification of that unit. It is recommended:

> **20.** That the appropriate regulatory authority conduct or cause to be conducted an analysis of the critical systems and their interrelationships on all drilling units in order to determine the adequacy of their response to emergency conditions. That there be subsequent periodic analyses as may be warranted.

Valuable lessons are to be learned from information about casualties, mishaps, and equipment failures. Where that information, if known by the other operators or contractors, could have the effect of making a safer workplace, it should be made available to all. It is recommended:

> **21.** That data be collected on equipment failures, accidents, dangerous occurrences, and any "significant events" as defined by the appropriate regulatory authority. That the data collected be systematically analyzed, indexed and disseminated to the offshore industry in a form that does not identify, if possible, the unit on which the event occurred.

"1. (c) . . . to inquire into, report upon and make recommendations in respect to all aspects of safety of life at sea, including the sufficiency of life saving equipment on board the *Ocean Ranger* and whether such life saving equipment was used or could have been used;"

The primary lifesaving equipment available to the crew during their evacuation of the ***Ocean Ranger*** included totally enclosed fibreglass lifeboats, inflatable life rafts and life preservers. The evidence revealed that only the lifeboats and life preservers were actually used. The ***Ocean Ranger*** had on board four lifeboats at the time of the loss but not all were available to the crew during their evacuation; one Watercraft lifeboat, located on the stern, may not have been fully provisioned and another Watercraft lifeboat was awaiting installation. A Harding lifeboat located on the stern was launched during evacuation with 30 or more crew members on board. Either during or shortly after the launching, it was badly damaged. The damage was sufficient to permit water to enter the boat and to contribute to a loss of stability leading to its capsize. The Watercraft lifeboat located at the stern of the rig was not recovered. Some of the crew may have used this lifeboat and it is probable that it was severely damaged or destroyed during launching. The Harding lifeboat located on the bow of the rig and the uninstalled Watercraft lifeboat were recovered. Both were severely damaged but showed no signs of having been occupied.

On February 15, 1982, the lifeboats represented the primary means of escape. To conclude that this means was inadequate is but to state the obvious. To launch a lifeboat even in calm weather is a difficult and risky operation and was rarely undertaken by the crew even though regulations required them to do so every three months. It is highly improbable that a lifeboat could be launched safely during a storm with the rig severely inclined. As there is no protected side on a rig, the chances of a successful evacuation are even more reduced.

Research into a better method of evacuation from drilling units is currently going on in a number of countries, but it appears to lack the incentive and the concerted effort necessary to see an early resolution of the problem. A solution, however, must be found. An effective system may well be costly and its development could be delayed if regulatory pressures are not maintained. Canadian authorities should consider the development of an effective evacuation system to be a matter of urgent priority and provide incentives for the development and installation of new systems. It is recommended:

> **22.** That Canadian authorities consider the development of an evacuation system that will provide an adequate and safe means of escape in foreseeable emergency and storm conditions to be a matter of the utmost priority and that they encourage through every means at their disposal the earliest development and use of a safe system.

As the majority of the personnel on a drilling unit are members of the industrial crew and as their industrial rather than marine skills improve with experience, the drilling unit, when on location, should be organized for lifeboat evacuations more like a passenger ship. The industrial crew should be regarded as passengers who will occupy the lifeboats in an evacuation and not as a crew capable of operating them. (The marine crew necessary for this purpose is discussed under item 1(e) of the Terms of Reference.) Because of the forward trim of the *Ocean Ranger*, two of its lifeboats could not be launched. Although it is recognized that the *Interim Standards* contain a similar provision, it is recommended:

> **23.** That drilling units be equipped with sufficient lifeboats for 200% of the crew.

The *Ocean Ranger* was equipped with sufficient inflatable life rafts to accommodate 200% of the crew. Six were recovered, all severely damaged; none had been occupied or used during the evacuation. They were manually or hydrostatically released and could only be entered from the sea. To gain access to them the crew would have been required to climb down scramble nets from a height of 70 feet or more. The effectiveness of this type of life raft as a means of evacuation from the deck of a MODU in storm conditions is highly questionable.

In 1979 the U.S. Coast Guard required the installation on the *Ocean Ranger* of either davit-launched life rafts or an acceptable substitute. ODECO elected to provide two additional lifeboats, but only one had been installed at the date of the loss. Although the davit-launched life rafts would be subject to the same limitations as were the lifeboats, the davit-launching mode of deploying them would be superior to that which existed on the *Ocean Ranger*. It is recommended:

> **24.** That life rafts required to be on drilling units be davit-launched.

The crew had available a sufficient quantity of life preservers for the evacuation. Many of the crew members were observed to be face down in the water and some were suspended beneath their life preservers. This may have been caused by the fact that the preservers were not worn properly. An unknown quantity of life preservers did not meet the buoyancy and righting moment criteria required by the U.S. Coast Guard. Although the life preservers were below required standards, that fact did not contribute to the loss of life.

The *Ocean Ranger* was not equipped with survival suits. There were no regulations at that time requiring them on MODUs operating off the East Coast of Canada, although eight months before the accident COGLA had issued a telex to all offshore operators recommending that survival suits be installed on all MODUs and support craft operating on the East Coast of Canada and in the Arctic. The industry and COGLA did not move quickly in implementing this recommendation. If survival suits had been provided at least a few of the crew might have survived. Since the casualty, COGLA has issued a directive to the effect that all drilling units must have sufficient survival suits for 200% of the crew.

"1. (d) . . . to inquire into, report upon and make recommendations in respect of all aspects of occupational health and safety which related to the officers and crew of the *Ocean Ranger*;"

The evidence suggests that in the first few months of the *Ocean Ranger*'s operations on Hibernia the accident rate among crew members was higher than the industry average. This was attributed, not unreasonably, to the influx of workers who were not experienced in offshore drilling or indeed drilling generally, and to the hazards inherent in this activity. The situation, however, improved over time and as of the date of the loss the accident record on the *Ocean Ranger* was comparable to that of other rigs operating in the area. There is no evidence to indicate that any matters relating to occupational health and safety caused or contributed to the loss of the rig and its crew.

"1. (e) . . . to inquire into and report upon and make recommendations in respect of the certification, training and safety of the officers and the crew and their respective responsibilities including those of the Master and the Toolpusher on board the *Ocean Ranger*;"

The *Ocean Ranger*, as previously noted, was not manned in accordance with the requirements of the *Certificate of Inspection* of the U.S. Coast Guard. Because there were no survivors, it cannot be said with certainty that failure to comply with these requirements contributed to the loss of the crew. It is, however, apparent that evacuation under the circumstances that existed on February 15, 1982 requires a high degree of skill and training. The operation of the rig's lifeboats should be the responsibility of specially trained lifeboat crews who could have regular industrial or marine assignments on the drilling units but who should, as a part of their assignments, be required to become specialists in the operation of lifeboats. The lifeboat drills for the lifeboat crews should be an integral part of their regular work. It is recommended:

> **25.** That drilling units be required at all times to have sufficient lifeboat crews to man lifeboats for 100% of the crew plus one additional lifeboat crew.
>
> **26.** That a lifeboat crew consist of four persons each holding a *Certificate of Efficiency* as a lifeboatman under the *Certification of Lifeboatmen Regulations* and that in addition to these requirements each prospective member of a lifeboat crew be required to establish to the satisfaction of the examiner that he is skilled and knowledgeable in:
>
> a) passenger control and crew organization in emergencies involving evacuation of the unit;
> b) survival procedures and techniques;
> c) search and rescue procedures and organization;
> d) the sea-keeping characteristics of the lifeboats;
> e) the operation of the lifeboat radio.
>
> **27.** That lifeboat crews be required to be trained in the use and operation of the type of lifeboat to which they are assigned and that this training include actual launching and operation of the lifeboat in the sea.
>
> **28.** That lifeboat crews be required to launch and operate the lifeboat in the sea at least twice each year. If this cannot be conveniently or safely done from the drilling unit then it should be done from a shore-based installation.

> **29.** That industry establish appropriate practices and incentives which recognize the importance of the lifeboat crews and which ensure adequate time and resources for their preparation and training.
>
> **30.** That drilling contractors be required by regulation to identify to inspectors during their periodic inspections of MODUs those crew members who are certificated lifeboatmen.

Under the regulations in force at the time it was the duty of the operator (Mobil) to ensure that all the rig's crew were instructed and trained in all necessary operational and safety procedures. Mobil, in fulfilling that obligation, relied on the owners of the drilling units. Canadian regulatory authorities relied on industry to determine the content and adequacy of the marine training program and to ensure that it was carried out. They established no minimum standards as a guide to industry, even for critical positions. Although the Marine Emergency Duties (MED) course was available at the time, it was not required by regulation and there was no evidence to indicate that any of the *Ocean Ranger* crew had taken it.

Under the 1984 COGLA guidelines there have been changes in the provisions relating to training. The crews of drilling units are now to take an approved marine emergency training course and to receive training in the use of rescue baskets; the personnel on moored units drilling on the Grand Banks are to be trained in the use of quick release mooring lines; appropriate marine personnel are to complete successfully training in ballast control for floating units including the use of back-up systems; the crews of standby vessels are to be trained in the use of the rescue equipment on such vessels.

These guidelines are merely an extension of the original requirement that persons be "adequately trained" and are too vague. Under the *Canada Shipping Act* a regulatory scheme is in place for establishing training requirements and examinations for proficiency of the crew of conventional ships. The regulatory authority itself determines the standards required and issues certificates of proficiency upon the satisfactory completion of training. There appears to be no reason why a similar scheme should not be established for the crew of offshore drilling units. It would not be necessary for every job category to be certificated but those responsible for the operation of the critical systems and for the overall safety of the rig should be included. It is recommended:

> **31.** That there be an assessment of the adequacy of training methods used on drilling units, with particular reference to "on-the-job" training methods; that the regulatory authority, in conjunction with representatives of the offshore industry, determine the adequacy of that training and establish minimum standards for specified positions.
>
> **32.** That within an appropriate time after the establishment of these standards, no person be permitted to hold a specified position on any drilling unit unless he holds a valid certificate issued by the appropriate authority or an equivalent certificate issued by the authority of another state where the course of training meets Canadian standards.
>
> **33.** That steps be taken by Canada to promote the establishment of uniform international standards for the certificates referred to in the preceding recommendation.

During the Public Hearings attention was focused on the training of ballast control operators. Neither of the two operators on the *Ocean Ranger* at the time of the loss had received any formal course of training but had learned through on-the-job experience. No formal training or testing was required by regulation. There was no manual available which fully described the operation of the ballast control panel or provided detailed drawings of the components of the panel.

Because of the critical function of the ballast control operator, specific recommendations are made with respect to training. The matters to be included in the recommended training program are not in any way intended to be complete but should be developed in detail in conjunction with the industry. It is recommended:

> **34.** That there be a course of training setting standards of knowledge and skill for ballast control operators. That upon successfully completing that course or by demonstrating to the regulatory authority the required skills and knowledge, an individual be granted a certificate to that effect.
>
> **35.** That the course of training referred to in the preceding recommendation include, *inter alia*:
>
> a) detailed instruction in the composition and operation of the ballast systems of drilling units;
>
> b) instruction in the appropriate use of the system in emergencies;
>
> c) instruction in all matters affecting the stability of drilling units;
>
> d) instruction in the practical operation of a ballast system by simulator and on a rig itself when available.
>
> **36.** That within an appropriate time after the establishment of these standards, no person be permitted to hold the position of ballast control operator on any drilling unit unless he holds a valid certificate duly issued by the appropriate authority or an equivalent certificate issued by the authority of another state where the course of training meets Canadian standards.
>
> **37.** That before assuming the position of ballast control operator for the first time on any drilling unit a certificated operator be required to receive orientation in or familiarization with the unique characteristics of the unit's ballast system and operating procedures, and with the alternative method, if any, of operating the ballast system.

The issue of respective responsibilities of the master and toolpusher evokes strong and varied opinions. For a time the question was simply "who should be in charge, the master or the toolpusher?". To residents of the Atlantic Provinces with their long seafaring history and traditions there is only one answer to that question. Rigs like the *Ocean Ranger* are self-propelled, have a crew and go on long ocean voyages. The mere thought of replacing the traditional marine crew with industrial personnel is foreign to the mind of a seafaring community.

Throughout the Public Hearings, however, as evidence was presented showing the complexity of a drilling unit's operations and the limited role of the master while the unit is in a moored condition, the answer became less clear. COGLA's reaction shortly after the loss was to issue a directive to the effect that a master mariner was to be in charge of the unit at all times while at sea even while moored. The directive has undergone some modifications and now states that:

> Drilling units shall at all times have one person on the unit clearly identified as responsible for the safety of the drilling unit and its crew. On floating drill units this person shall: be qualified in marine matters; be experienced in drilling unit operations; and, possess a recognized master mariner's certificate. This requirement recognizes the need for the person ultimately responsible for safety to make decisions in full consultation with the person responsible for drilling operations.

That directive is equivocal; it does not deal with the issue of command but only with the question of who shall be responsible for the safety of the rig and its crew. It makes no reference to formal training in drilling unit operations. While the philosophy behind this directive is neither accepted nor rejected at this time, it is believed that the requirement should be expanded to include formal training in drilling unit operations. It is recommended:

> **38.** That the certificate held by a ballast control operator who has not worked full-time in that capacity for an appropriate period of time become invalid on the expiry of that period and that the operator be required to complete a prescribed refresher course in order to validate his certificate.
>
> **39.** That the current COGLA guideline regarding the qualifications of the person responsible for the safety of the drilling unit and its crew be amended to include training in drilling unit operations and in the operation of the unit's ballast control system.

The importance of the question of command and its modification is recognized. The evidence heard in Part I was directed primarily at command on the *Ocean Ranger*. A different command structure existed on the *Zapata Ugland*, where the master was in charge at all times, and on the *SEDCO 706*, where the toolpusher was in charge and there was no master on the rig. Consideration of the question should not be governed by labels but rather by the qualifications necessary for the person in charge to be able to exercise competent command. There must also be considered the question of whether that command should change from one qualified type of commander to another when the type of activity taking place on the unit changes. It is also necessary to consider the command structure of units other than semisubmersible units and whether special command arrangements are necessary where, for example, there are requirements to disconnect rapidly on account of the presence of ice. A wide range of views will undoubtedly be presented during Part II of the inquiry and more informed recommendations can then be made.

The command structure on the *Ocean Ranger* was stated in the foreword to the *Booklet of Operating Conditions* where it was specified that during all industrial operations the toolpusher is designated as the "person in charge" of the unit. While the rig is being prepared for a move and while in transit, the barge master, a master mariner, is designated as being in complete charge. The *Booklet* also states that "the barge master is responsible for the stability of the unit at all times". On paper the command structure appears clear. The *Booklet*, however, was designed primarily for ballast control operators and was not readily available to all personnel. Testimony indicated that some crew members were in doubt from whom they would take orders in an emergency. An appropriate command structure requires that the lines of authority and responsibility be clear to all concerned, and that those entrusted with specific responsibilities have the necessary authority.

It is difficult to segregate the issue of command structure from the qualifications and training of those in command. The *Ocean Ranger* toolpusher, although experienced in offshore drilling, had no formal marine qualifications or training. On him, however, fell the responsibility to order the abandonment of the rig because of a lack of stability in extreme storm conditions. Apart from limited previous offshore experience, the master on board had not been to sea for a number of years, and his position in the command structure had been seriously weakened by the fact that, although he was responsible for the stability of the unit, the toolpusher had ordered him, as a result of the February 6 incident, not to touch the ballast control panel.

A command structure which is not absolutely clear to all concerned, which fixes responsibility without sufficient authority, and in which critical decisions can be taken without access to or availing of all the necessary expertise and experience undermines an adequate level of safety. There was no evidence, however, that the command structure itself on the *Ocean Ranger* was a factor contributing to the loss.

The local preference policies of the Government of Newfoundland may have affected the certification and training of the crew of the *Ocean Ranger*. The evidence indicated, however, that the conflict over local preference for labour was not a contributing factor to the loss of the rig or its crew. Nevertheless, guidelines requiring a very rapid phase in of local residents can affect the overall level of safety of the drilling operations. In light of the province's inability to ascertain whether the local labour force can supply the required number of *qualified* workers, it is recommended:

> **40.** That the Offshore Employment Register be scrutinized to ensure that individuals listed for employment on drilling units and support craft are qualified.
>
> **41.** That the rate of phase in of local residents be controlled, in consultation with industry, to ensure that the highest level of safety is maintained.

"1. (f) . . . to inquire into, report upon and make recommendations on the search and rescue response and any other emergency response thereto, both from within Newfoundland and elsewhere;"

The response of personnel on and off shore to the request for assistance from the *Ocean Ranger* included air and marine resources under contract to Mobil and the Search and Rescue (SAR) resources of the Government of Canada. Mobil was the only operator drilling on the Grand Banks in February 1982. Its emergency communications officer that night, who was responsible for mobilizing human and physical resources, was Merv Graham, the drilling superintendent. The shore base received little warning of the pending tragedy but when the request for help came, action was prompt. SAREC St. John's was immediately alerted, the crews of two Sikorsky helicopters were mustered and the *Boltentor* and *the Nordertor*, the standby vessels for the *Zapata Ugland* and the *SEDCO 706*, were directed to proceed to the *Ocean Ranger*. The *Seaforth Highlander*, the standby vessel for the *Ocean Ranger*, was requested directly by the rig at 1:05 a.m. to come to close standby. It is apparent from the evidence, however, that communications emanating from Mobil shore-base were neither accurate nor prompt, with consequent misunderstanding, confusion and delay. SAREC was told shortly after it was alerted, that there were three ships in the area of the *Ocean Ranger* and that three or four helicopters were being dispatched to evacuate the crew. This misinformation may have contributed in part to the lack of any apparent sense of urgency in the SAR response. It is evident that Mobil's key personnel had not practised adequately their emergency procedure roles. Graham, the emergency communications officer that night, Fraser, the on-site co-ordinator on the *SEDCO 706* and Flynn, the shore-based radio operator were laden throughout that period with duties and responsibilities for which they were not qualified by training or experience. There are now other operators on the Grand Banks and they have developed contingency plans for joint and co-ordinated response to emergencies. It is recommended:

> **42.** That periodic exercises be held by industry for the purpose of training its key personnel in what would be required of them in the event of an emergency.

Mobil promptly ordered the deployment of helicopters and supply vessels to aid the *Ocean Ranger* but their response, because of the prevailing weather conditions, was delayed. Before the first helicopters were airborne (3:22 a.m.) the rig had capsized and sunk. When they arrived at the site, they were too late to effect any rescue. Their role was to assist the supply vessels in searching for survivors. The helicopters were not equipped with rescue equipment such as hoists and rescue baskets nor were their pilots trained in marine rescue operations.

The crews of the supply vessels that responded to the casualty were hampered in their efforts by severe winds and sea conditions, inadequate rescue equipment and the design of the vessels themselves. COGLA regulations stipulate that there be a suitable standby craft for each rig but what is suitable is not defined. The supply vessels on standby duty on the Hibernia Field were designed for carrying heavy cargo, towing icebergs and for handling anchors. Their solid bulwarks without appropriate gates, their high freeboard, the rubbing strake and the configuration of the ships hampered rescue operations.

COGLA also required each standby vessel to have sufficient capability and equipment to evacuate all personnel from the rig and have first aid equipment to treat persons suffering from hypothermia. None of the vessels had special rescue equipment such as a crane with basket or net nor did they have the meagre amount of rescue equipment required under the regulations. The crews had not been trained in rescue operations nor in the treatment of hypothermia. Reasonable foresight ought to have dictated that vessels in a standby role be appropriately designed, adequately equipped and properly manned for rescue operations.

The *Boltentor* reached the site of the *Ocean Ranger* after it had been abandoned, *the Nordertor* after it had capsized. Both arrived too late to participate in any rescue attempt. The *Seaforth Highlander*, on standby duty to the *Ocean Ranger*, had a special duty and responsibility for that rig but when help was urgently required, she was eight miles away. COGLA, neither in its regulations nor in any guidelines issued to the industry, specified the standby distance nor was any written instruction on the matter issued by Mobil. Captain Duncan, master of the *Seaforth Highlander*, testified that only upon arrival at the site was he informed that he should stay, weather permitting, within two miles of the rig and he issued standing orders accordingly. The captains of the other supply vessels, in spite of the heavy seas, kept within a half an hour of their respective rigs that night. Duncan, however, was reluctant to turn his vessel, fearing for the integrity of her structure and the safety of her crew. Recognizing the responsibility of a captain and taking into account the actions of the other captains that night, it is concluded that Captain Duncan ought to have been in closer standby.

The *Seaforth Highlander* reached the *Ocean Ranger* after it had been abandoned and endeavoured to save the survivors in one of the lifeboats. Without safety lines and with the deck awash, the *Seaforth Highlander* crew strove valiantly to save the men in the lifeboat and displayed courage in the best traditions of the sea. Had the vessel been differently designed and better equipped with the crew trained in the use of that equipment, and had the men in the lifeboat been wearing survival suits, some might have been rescued. Since the loss of the *Ocean Ranger* the guidelines governing standby vessels have been improved with additional rescue equipment such as fast rescue craft and rescue baskets now required. The crews are to be trained in rescue operations. It is recommended:

> **43.** That there be an immediate assessment by the appropriate authority of the capability and suitability of the various types of vessels now serving as standby craft to drilling units off Eastern Canada to perform adequately their rescue role.
>
> **44.** That the primary responsibility of a vessel acting in the capacity of a standby vessel for a drilling unit be to standby within the prescribed time or distance from the unit and be ready at all times to render whatever assistance to the rig and its crew that may be required.
>
> **45.** That no vessel be permitted to act as a standby vessel if its cargo would interfere with its ability to render assistance to the rig and its crew.
>
> **46.** That there be established training standards for the crew of any vessel which is to be used as a standby vessel and that training embodying these standards be required.
>
> **47.** That the training embodying these standards include, *inter alia*, instruction in:
>
> a) the use and operation of all rescue and emergency aids with which the standby vessel is equipped;
>
> b) the treatment of survivors for the injuries and other conditions from which they may be suffering upon rescue;

c) the deployment of the standby vessel and its equipment to render effective assistance to the drilling unit and its crew in various emergencies that may occur.

48. That the crews of standby vessels, while on standby duty, be exercised in the use of the vessels' rescue equipment at least weekly, weather permitting.

49. That the person in command of the rig and the master of the standby vessel be required to log any occasion when the standby vessel exceeds the prescribed standby time or distance. That where the standby vessel exceeds the prescribed time or distance without the consent of the person in command of the rig, both the person in command of the rig and the master of the standby vessel be required to submit written reports to the regulatory authority.

SAREC was notified by Mobil at 1:06 a.m., and RCC Halifax was notified by SAREC at 1:21 a.m. that the *Ocean Ranger* had serious problems. At 1:31 a.m. RCC Halifax alerted 103 Rescue Unit Gander; at 2:24 a.m. it tasked the Buffalo at Summerside, Prince Edward Island, and at 4:40 a.m. the Aurora at Greenwood, Nova Scotia, and appointed it the "on-scene" commander. SAREC was requested by RCC Halifax at 1:36 a.m. to issue an All Ships Broadcast but it was not issued until 2:04 a.m.

Time is of the essence in an emergency yet time was lost in seeking information regarding the coordinates of the rigs in the Hibernia Field, their radio frequencies, the dimensions of the *Ocean Ranger*, the size of its crew, and the location, capacity and call signs of the commercial helicopters. This information should have been already available to RCC Halifax. Neither RCC nor SAREC had a contingency plan for a major marine disaster nor were they in a state of preparedness, if one did occur. There was no sense of urgency displayed by either of them in mustering resources and in responding to the requests for help. Actions in transmitting communications, tasking resources and sending out an All Ships Broadcast, were characterized by undue and unexplained delay. This delay may be due in part, but only in part, to the information given by Mobil that three ships were already in the area and commercial helicopters were being mobilized to evacuate the crew. Nevertheless, an hour was to pass before a fixed wing aircraft was tasked, three hours were to pass before an on-scene commander was appointed and eight hours before they arrived on the scene.

The SAR helicopters at Gander were manufactured some twenty years ago and although they have undergone extensive upgrading they did not have radar, an automatic flight control system, a hover coupler system or VHF/FM marine radio. Consequently they were unable to fly below low lying cloud at night; they could not hover in a fixed position close to the water without pilot assistance during rescue operations nor could they communicate directly with vessels during a rescue attempt. An upgrading program (SARCUP) has been initiated to remedy these deficiencies. The main weakness of the Labrador/Voyageur, however, is its relatively short range and consequent lack of endurance for rescue missions offshore. There are also certain weather conditions which restrict its operation.

The SAR helicopters, because of weather conditions, could not leave Gander until after 6:30 a.m. and arrived too late to participate in a rescue attempt. But they would have been too late even if conditions had been ideal, and if they had been in St. John's, fully fueled and with crews on 30 minute standby. The rig was evacuated between 1:30 a.m. and 2:00 a.m. and the lifeboat alongside the *Seaforth Highlander* capsized at 2:38 a.m. The earliest possible time of arrival of the SAR helicopters would have been 2:55 a.m. It is recommended:

> **50.** That the Rescue Co-ordination Centre in Halifax and the Search and Rescue Emergency Centre in St. John's have available, for instant retrieval, all relevant information with respect to offshore drilling operations on the continental shelf within their respective zones of responsibility that might be required in the event of a marine casualty. That this information include relevant data not only with respect to the drilling units but also with respect to the contracted helicopters and supply vessels.
>
> **51.** That upon receiving a forecast issuing a storm warning for an area in which drilling units are situated the Rescue Co-ordination Centre at Halifax obtain SURPICs of all ships within a radius of approximately 100 miles of the units every 6 hours commencing 6 hours before the storm is forecast to reach the location of the drilling units.
>
> **52.** That the practice of Canadian Coast Guard radio operators waiting for written confirmation of the recorded verbal instructions to issue urgent messages be discontinued. That where personnel at either RCC or SAREC in St. John's are of the view that an urgent message should be transmitted, instructions be issued directly to Coast Guard radio, and, where relevant, the agency giving such instructions inform the other.
>
> **53.** That as a matter of urgent priority Canada complete its SARCUP program to upgrade existing SAR helicopters and obtain others capable of longer ranges and with endurance for rescue missions offshore.
>
> **54.** That Canada develop a contingency plan outlining the procedures to be followed in the event of a major marine disaster and that joint exercises be periodically held to train key personnel of SAREC, RCC, industry both on shore and on the rigs and standby vessels in what they would be required to do in the event of rig evacuation under emergency conditions.

COGLA, in its December 1983 *Guidelines to Operators – East Coast*, provided that "... operators on the Grand Banks shall, on a joint and continuing basis, maintain a helicopter dedicated to search and rescue with personnel trained and qualified in the use of such equipment ...."

The communiqué accompanying the guideline elaborated that this would be a *full-time* dedicated search and rescue helicopter, that the Department of National Defence (DND) would assess the search and rescue programs of the operators on a continuing basis, and that DND would provide search and rescue training for industry personnel.

COGLA, in its April 1984 guidelines and procedures provided that:

> ... drilling units are to be evacuated when wind speed exceeding 90 per cent of the design standards of the unit are forecast, provided that such an evacuation, in the opinion of the person in command of the drilling unit, can be conducted in a safe manner. Dynamically-positioned drilling units will have the option to evacuate all rig personnel or to move away from the forecast storm track ...

This guideline recognizes the fact that existing evacuation methods are inadequate during severe storms and directs that precautionary evacuation take place. Because of the transitory nature and the doubtful enforceability of guidelines as opposed to regulations, it is recommended:

> **55.** That when wind speeds are forecast which exceed 90 per cent of the design parameters of a drilling unit, the crew from that unit be evacuated before the storm arrives, provided that the evacuation, in the opinion of the person in command of the drilling unit, can be conducted in a safe manner.
>
> **56.** That there be required a full-time search and rescue dedicated helicopter, provided by either government or industry, fully equipped to

search and rescue standards, stationed at the airport nearest to ongoing offshore drilling operations, and that it be readily available with a trained crew able to perform all aspects of rescue.

"1. (g) . . . to inquire into, report upon and make recommendations in respect of oil pollution prevention procedures and whether the drill hole was left in a safe condition prior to or at the time of the casualty;"

Subsequent to the loss of the *Ocean Ranger* the blowout preventer was removed along with the drill string remaining in the hole at time of disconnect. On the basis of an assessment of the Hibernia J-34 Re-Entry and Suspension Program (Appendix F, Item 1), it is concluded that the well was properly secured before the loss, that there was no escape of well fluids at any time as a result of the casualty and that the drill hole was left in a safe condition prior to the time of the casualty. The equipment used and the procedures followed were suitable for the purpose of preventing oil pollution. No recommendation is necessary.

"1. (h) . . . to inquire into, report upon and make recommendations in respect of any acts or omissions of the owner, the charterer, the operator or any contractor in respect thereto;"

The preceding commentary outlines many areas in which the *Ocean Ranger* was deemed to be deficient in its design and manner of operation. Section 1 (h) of the Terms of Reference refers to acts or omissions which are contrary to law or which may amount to negligence. Based on the evidence, it has been concluded:

> A. That ODECO, contrary to U.S. Coast Guard Regulations, omitted to provide the *Ocean Ranger* with the required number of qualified marine personnel and had not met U.S. Coast Guard requirements for lifesaving equipment.
>
> B. That ODECO, contrary to U.S. Coast Guard Regulations, did not have a valid *Certificate of Inspection* for the *Ocean Ranger* at the time of its loss.
>
> C. That Mobil (the operator), contrary to COGLA Drilling Regulation 151 (a) failed to ensure that ". . .every person employed on a drilling program receives instructions and training in respect of all operational and safety procedures that the person may be required to carry out during the course of his duties during such employment. . . ."
>
> D. That ODECO, Mobil, and other contractors failed to provide survival suits for their personnel on board the *Ocean Ranger*.
>
> E. That Mobil and/or Seaforth Fednav failed to inform Captain Duncan adequately of his duties as master of a standby vessel.
>
> F. That neither Mobil, Seaforth Fednav, nor Crosbie Offshore properly equipped or caused to be equipped the standby vessels with proper rescue equipment with which to discharge adequately their responsibilities as standby vessels.

"1. (i) to inquire into, report upon and make recommendations on any other related matter."

The provision of timely and accurate weather forecasting is critical to the safe management of offshore drilling operations. Weather forecasts which predict environmental conditions which require the institution of safety measures must be taken into account and acted upon in order to ensure the safety of the operation. The crew of the rig must be able to interpret these forecasts properly if appropriate action is to be taken. The existence of a misunderstanding between NORDCO, Mobil and ODECO regarding the terminology used in the forecasts served to limit the effectiveness of this information. Testimony, however, indicated that operational decisions were made not on the basis of weather forecasts, but in response to weather conditions as they occurred. This general disregard for weather forecasting with respect to drilling operations and the operating history of the *Ocean Ranger* suggest that even if the NORDCO forecast had been properly understood, defensive action such as deballasting the rig would not have been taken. Accordingly it is concluded that the misunderstanding was not of itself a factor contributing to the loss of the rig. It is recommended:

> 57. That government and industry jointly take steps to ensure that a standardized weather reporting and forecasting system is adopted and understood.
>
> 58. That when a forecast predicts one or more environmental parameters which require defensive or emergency procedures, and when the required procedures are not in fact taken, a notation to that effect be logged by the person in command of the drilling unit, and a written report be forwarded by the person in command to the regulatory authority within 48 hours setting out the details of the forecast, the established parameter or parameters, the action required to be taken and the reason for not taking that action.

Evidence indicated a tendency on the part of offshore personnel not to report, or to delay reporting significant events to shore base or to the regulatory authority. A minor fuel spill, the listing incident of February 6, 1982, and the broken portlight were not the subject of timely communication, even when a report was required by regulation. One of the predominant objectives of regulatory control is the prevention of events which can lead to injury or loss of life. Failure, however, to report these events at the time that they occur significantly diminishes the effectiveness of this function. Some of the difficulty is no doubt caused by the lack of a clear definition of a significant event. It is recommended:

> 59. That the regulatory authority, in consultation with industry, more adequately define, by way of examples, the meaning of the term "significant event" which, should one occur, must be reported to the regulatory authority within the prescribed time.
>
> 60. That where a drilling unit exceeds its allowable KG at any time, it be deemed to be a "significant event" and a detailed written report and explanation be made by the person in command to the regulatory authority.

Throughout the public hearings it became evident that several systems of measurement were being used offshore. Wind speeds were forecast in knots and reported in miles per hour while the inland radio forecast gives them in kilometers per hour. Distances were alternately given in nautical miles, statute miles or cables. While this mixture of systems did not in any way contribute to the loss of the *Ocean Ranger* it is seen as a potential source of problems for the industry which can and should be avoided. It is recommended:

> 61. That in order to avoid misunderstanding and confusion in reporting procedures there be a single system of measurements used in all reports.

Examination of the *Ocean Ranger*'s ballast control system identified weaknesses not only in its design and in the training of those who operated it, but also in the manner in which the system was operated and managed. Critical stability information was not regularly tabulated or reviewed, aids for completing stability calculations were not made available, adequate written instruction in the use of the system was not available, particularly for junior operators, and there were indeterminate periods of time during which the ballast control room was unmanned.

The public address system, at least to the extent to which it could be operated from the ballast control room, was damaged by sea water when the portlight broke. Examination of the wiring plan, together with testimony, indicated that this system was on the same circuit as the fire and abandon ship alarms. A muting system rigged by the crew to reduce noise in the accommodations area required that the alarm system be triggered in order to use the public address system at full volume in this area.

In addition, there was no power supply to the public address system which was independent of the main and emergency generators. In the event of loss of all power, no rig-wide communication was possible. It is recommended:

> **62.** That the public address and emergency alarm systems each be independent of the other and that each be operable for up to six hours in the event of a loss of electrical generation capability.
>
> **63.** That there be a separate operating manual for the ballast system describing in detail its mechanical, electrical, pneumatic or hydraulic functions and components, its limitations, any alternate method of operation, and instructions for the systematic location of faults and their correction. That it be the responsibility of the person in overall charge of the ballast system to assure himself that the contents of this manual are known and understood by each ballast control operator.
>
> **64.** That both this operating manual and the *Booklet of Operating Conditions* contain detailed instructions for the guidance of ballast control operators and others for operations in other-than-normal conditions, including, but not limited to, intentional slackening of anchor lines; dumping or shifting of mud, drill water or other weight; breakage of one or more anchor lines; accidental flooding of various combinations of lower tanks; accidental flooding of one or more chain lockers and spaces in the upper hull, and inclination of the rig because of second order wave effects.
>
> **65.** That ballast control operators be required to calculate and log the drilling unit's transverse and longitudinal angles of inclination weekly. That where the calculated moments of either are in excess of 1,000 foot tons from the actual moments (as determined by the inclinometers) the amount of the variation be entered in the log and contained in the next morning report.
>
> **66.** That the primary control centre for the ballast system on a drilling unit be manned and attended at all times.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

THE ROYAL COMMISSION

APPENDIX A

APPENDIX A

THE ROYAL COMMISSION

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Item A-1

Terms of Reference
Canada

The Order of the Governor-in-Council No. PC 1982-819 dated the 17th day of March A.D. 1982

Certified to be a true copy of a Minute of a Meeting of the Committee of the Privy Council, approved by His Excellency the Governor General on the 17 March, 1982.

WHEREAS the Committee of the Privy Council has had before it a report of the Prime Minister submitting that it is essential that an Inquiry be made into the matters hereinafter set forth in paragraphs 1 to 3 below.

Therefore the Committee of the Privy Council on the recommendation of the Prime Minister advise that the Honourable T. Alexander Hickman, Chief Justice of the Trial Division of the Supreme Court of Newfoundland, the Honourable Gordon A. Winter, Moses Morgan, Esq., Fintan J. Aylward, Queens Counsel, Bruce Pardy, Esq. and Jan Furst, Esq., all of the Province of Newfoundland, be hereby appointed Commissioners under Part I of the Inquiries Act to:

1. Inquire into and report upon the loss of all members of the crew of the semi-submersible self-propelled drill rig *Ocean Ranger*, and of the *Ocean Ranger*, on or about the 15th day of February, 1982 on the Continental Shelf off Newfoundland and Labrador, the reasons and causes therefor and, without restricting the generality of the foregoing, to inquire into, report upon and make recommendations in respect of the following matters:
    (a) the design, construction and stability of the *Ocean Ranger* and its suitability to conduct marine and drilling operations on the Continental Shelf off Newfoundland and Labrador;
    (b) inspection, inspection procedures, licensing, classification and certification pertaining to the conduct of marine drilling operations by the *Ocean Ranger* on the Continental Shelf off Newfoundland and Labrador;
    (c) all aspects of safety of life at sea, including the sufficiency of life saving equipment on board the *Ocean Ranger* and whether such life saving equipment was used or could have been used;
    (d) all aspects of occupational health and safety which related to the officers and crew of the *Ocean Ranger*;
    (e) the certification, training and safety of the officers and the crew and their respective responsibilities including those of the Master and the Toolpusher on board the *Ocean Ranger*;
    (f) the search and rescue response and any other emergency response thereto, both from within Newfoundland and elsewhere;
    (g) oil pollution prevention procedures and whether the drill hole was left in a safe condition prior to or at the time of the casualty;
    (h) any acts or omissions of the owner, the charterer, the operator or any contractor in respect thereto; and

Terms of Reference
Province of Newfoundland

The Lieutenant Governor-in-Council's Commission dated the 16th day of March A.D. 1982

ELIZABETH THE SECOND by the Grace of God
of the United Kingdom, Canada and Her Other
Realms and Territories QUEEN, Head of the
Commonwealth, Defender of the Faith.

W. Anthony Paddon
Lieutenant-Governor

COMMISSION

TO: The Honourable T. Alexander Hickman,
Chief Justice of The Trial Division
of the Supreme Court of Newfoundland
(Chairman),
The Honourable Gordon A. Winter, C.C., LL.D.,
Moses O. Morgan, C.C.,
Fintan J. Aylward, Q.C.,
Jan Furst, Esq., and
Bruce Pardy, Esq.

WHEREAS it appears desirable and expedient that an enquiry be made into the loss of life resulting from the sinking of the *Ocean Ranger* on February 15th., 1982.

NOW KNOW YE that under and by virtue of The Public Enquiries Act Chapter 314 of The Revised Statutes of Newfoundland, 1970, We, by and with the advise of Our Executive Council of Our Province of Newfoundland, reposing great trust and confidence in your knowledge, integrity and ability, have constituted and appointed and do by these presents constitute and appoint you the said T. Alexander Hickman, Gordon A. Winter, Moses O. Morgan, Fintan J. Aylward, Jan Furst, and Bruce Pardy
to be Commissioners to hold an enquiry into the matters following, that is to say:

1. Enquire into and report upon the loss of all members of the crew of the semi-submersible self-propelled drill rig *Ocean Ranger*, and of the *Ocean Ranger*, on or about the 15th. day of February, 1982, on the Continental Shelf off Newfoundland and Labrador, the reasons and causes therefor and, without restricting the generality of the foregoing, to enquire into, report upon and make recommendations in respect of the following matters:
    (a) the design, construction and stability of the *Ocean Ranger* and its suitability to conduct marine and drilling operations on the Continental Shelf off Newfoundland and Labrador;
    (b) inspection, inspection procedures, licensing, classification and certification pertaining to the conduct of marine drilling operations by the *Ocean Ranger* on the Continental Shelf off Newfoundland and Labrador;
    (c) all aspects of safety of life at sea, including the sufficiency of life saving equipment on board the *Ocean Ranger* and whether such life saving equipment was used or could have been used;

(i) any other related matter.

2. Inquire into, report upon and make recommendations with respect to:

   (a) both the marine and drilling aspects of practices and procedures in respect of offshore drilling operations on the Continental Shelf off Newfoundland and Labrador and without restricting the generality of the foregoing, the matters referred to in paragraphs 1.(a) to 1.(e) as they related to other drilling units conducting marine and drilling operations on the Continental Shelf off Newfoundland and Labrador; and

   (b) to the extent necessary and relevant, such practices and procedures in other Eastern Canada offshore drilling operations.

The Committee further advise that:

(a) the establishment of this Commission and the appointment of the Commissioners hereunder is without prejudice to both the claim of the Government of Canada and the claim of the Government of Newfoundland to legislative jurisdiction and proprietary rights on or in respect of the Territorial Sea or the Continental Shelf off Newfoundland and Labrador; and

(b) notwithstanding the terms of reference set forth in this Order in Council, the Commissioners be directed not to consider, comment upon nor make recommendations in respect of the claims to jurisdiction and rights aforesaid.

The Committee further advise that:

(a) the Honourable T. Alexander Hickman be the Chairman of the Commission and that the Honourable Gordon A. Winter be Vice-Chairman of the Commission;

(b) the Chairman and the Vice-Chairman be authorized, after consultation with the other Commissions, to:

   (i) adopt such practices and procedures for all purposes of the Inquiry as may from time to time be necessary for the proper conduct of the Inquiry and, after consultation with the other Commissioners, vary those practices and procedures from time to time;

   (ii) engage the services of counsel to aid and assist the Commissions in the Inquiry at such rates of remuneration and reimbursement as may be approved by the Treasury Board;

   (iii) rent such space for offices and hearing rooms in consultation with the Department of Public Works and according to the practices of the Department;

   (iv) engage the services of such accountants, engineers, technical advisors or other experts, clerks, reporters and assistants as they may deem necessary or advisable, at such rates of remuneration and reimbursement as may be approved by the Treasury Board; and

   (v) exercise all powers conferred upon them by subsection (2) to subsection (4) of section 11 of the Inquiries Act;

(d) all aspects of occupational health and safety which related to the officers and crew of the *Ocean Ranger*;

(e) the certification, training and safety of the officers and the crew and their respective responsibilities including those of the Master and the Toolpusher on board the *Ocean Ranger*;

(f) the search and rescue response and any other emergency response thereto, both from within Newfoundland and elsewhere;

(g) oil pollution prevention procedures and whether the drill hole was left in a safe condition prior to or at the time of the casualty;

(h) any acts or omissions of the owner, the charterer, the operator or any contractor in respect thereto; and

(i) any other related matter.

2. Enquire into, report upon and make recommendations with respect to:

   (a) both the marine and drilling aspects of practices and procedures in respect of offshore drilling operations on the Continental Shelf off Newfoundland and Labrador and, without restricting the generality of the foregoing, the matters referred to in paragraphs 1.(a) to 1.(e) as they relate to other drilling units conducting marine and drilling operations on the Continental Shelf off Newfoundland and Labrador; and

   (b) to the extent necessary and relevant, such practices and procedures in other Eastern Canada offshore drilling operations.

AND WE DO advise that the establishment of this Commission and your appointment as Commissioners hereunder is without prejudice to both the claim of the Government of Canada and the claim of the Government of Newfoundland to legislative jurisdiction and proprietary rights on or in respect of the Territorial Sea or the Continental Shelf off Newfoundland and Labrador;

AND FURTHER, not withstanding the terms of reference as set forth in this your Commission, We hereby direct you not to consider, comment upon nor make recommendations in respect of the claims to jurisdiction and rights aforesaid;

AND FURTHER, We do authorize

   (i) the Honourable T. Alexander Hickman to be the Chairman of the Enquiry and the Honourable Gordon A. Winter to be Vice-Chairman of the said Enquiry;

   (ii) the Chairman and Vice-Chairman, after consultation with the other Commissioners, to:

      (A) adopt such practices and procedures for all purposes of the enquiry as may from time to time be necessary for the proper conduct of the enquiry and, may, after consultation with the other Commissioners, vary those practices and procedures from time to time;

      (B) engage the services of counsel to aid and assist the Commissioners in the enquiry at such rates of

3. The Commissions be authorized to sit at such times and in such places, and to view such locations, both in and outside Canada, as the Chairman may, after consultation with the other Commissioners, from time to time decide; and

4. The Commissions be authorized to submit interim reports to the Governor in Council from time to time.

The Committee further advise that the Commissioners be directed to submit a final report to the Governor in Council with all reasonable dispatch and file with the Dominion Archivist the papers and records of the Commission as soon as reasonably may be after the conclusion of the Inquiry.

And the Committee further advise that pursuant to section 37 of the Judges Act, the Honourable T. Alexander Hickman be authorized to act as a Commissioner and Chairman for the purpose of the said Inquiry.

CERTIFIED TO BE A TRUE COPY

CLERK OF THE PRIVY COUNCIL

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remuneration and reimbursement as may be approved by the Lieutenant-Governor in Council;

(C) rent such space for offices and hearing rooms as they deem necessary and advisable at such rates as may be approved by the Lieutenant-Governor in Council;

(D) engage the services of such accountants, engineers, technical advisors or other experts, clerks, reporters and assistants as they may deem necessary or advisable, at such rates of remuneration and reimbursement as may be approved by the Lieutenant-Governor in Council;

(E) exercise all powers conferred upon them by Section 5 of The Public Enquiries Act;

(iii) you, the said Commissioners, to sit at such time and in such places, and to view such locations, both in and outside Canada, as the Chairman may, after consultation with the other Commissioners, from time to time decide;

(iv) you, the said Commissioners, to submit interim reports to the Lieutenant-Governor in Council from time to time.

AND WE DO, by these Presents, confer upon you, the said Commissioners, the power of summoning before you any witness or witnesses and of requiring all such witnesses to give evidence orally or in writing upon oath or upon solemn affirmation, and to produce such documents and things as you, the said Commissioners, may deem requisite to the full investigation of the matters you are appointed to enquire into.

AND FURTHER, We require you, with as little delay as possible to report to Us your findings upon the matters herein submitted for your consideration together with the papers and records of the Commission.

AND FURTHER, We do authorize the Honourable T. Alexander Hickman to act as a Commissioner and Chairman for the purpose of the said Enquiry, pursuant to Section 37 of The Judges Act.

IN TESTIMONY WHEREOF, We have caused these Our Letters to be made Patent and the Great Seal of Newfoundland to be hereunto affixed.

WITNESS: Our trusty and well-beloved the Honourable W. Anthony Paddon, Member of Our Order of Canada, Lieutenant-Governor in and for Our Province of Newfoundland.

AT OUR GOVERNMENT HOUSE in Our City of St. John's this *16th* day of *March* in the year of Our Lord one thousand nine hundred and eighty-two and in the thirty-first year of Our Reign.

BY COMMAND, Deputy REGISTRAR GENERAL

Item A-2
Formal Order of Commission

IN THE MATTER OF THE INQUIRY
INTO THE LOSS OF THE *OCEAN*
RANGER ON OR ABOUT THE 15TH
DAY OF FEBRUARY, 1982, ON THE
CONTINENTAL SHELF OFF
NEWFOUNDLAND AND LABRADOR

WHEREAS the Governor-in-Council has been pleased pursuant to Section 2 of **The Inquiries Act** to cause an Inquiry to be made into the loss of all members of the crew of the semi-submersible self-propelled rig *Ocean Ranger* and of the *Ocean Ranger* on or about the 15th day of February, 1982, on the Continental Shelf off Newfoundland and Labrador.

NOW, therefore, pursuant *IT IS HEREBY ORDERED AND DECLARED* that:

1. No person shall remove, touch or otherwise disturb in any manner or cause or permit to be removed, touched or disturbed the said *Ocean Ranger* or any of its gear or equipment at Latitude 46 degrees 43 minutes 34 seconds North, Longitude 48 degrees 50 minutes 11 seconds West.

2. No person or vessel shall approach or cause or permit an approach to be made closer than 500 meters from the location of the said *Ocean Ranger* at Latitude 46 degrees 43 minutes 34 seconds North, Longitude 48 degrees 50 minutes 11 seconds West for any purpose except upon such terms and conditions as may be prescribed by the Commissioners.

Dated at St. John's in the Province of Newfoundland this 22nd day of March A.D., 1982.

BY ORDER OF THE COMMISSIONERS

CHAIRMAN

TO:

ODECO Drilling of Canada Limited
Topsail Road
St. John's, Newfoundland

Mobil Oil Canada Limited
Atlantic Place
St. John's, Newfoundland

Item A-3
Practice and Procedure Rules

SHORT TITLE

1. These Rules may be cited as the *Ocean Ranger* Marine Disaster Inquiry Rules.

APPLICATION

2. These Rules apply to that portion of the inquiry of the Royal Commission on the *Ocean Ranger* Marine Disaster contained in the paragraph 1 of Order-in-Council PC 1982-819 and paragraph 1 of the Lieutenant Governor-in-Council's Commission dated the 16th day of March A.D. 1982.

INTERPRETATION

3. In these Rules:

"Act" means the **Inquiries Act**, R.S.C. 1970, c. 1-13.

"Chairman" means the person appointed by the Governor-in-Council and the Lieutenant Governor-in-Council to be Chairman of the Commission.

"Commission Counsel" means Counsel appointed by the Commissioners and the Lieutenant Governor-in-Council to assist them in their inquiry.

"Commissioner" means a person appointed by the Governor-in-Council and the Lieutenant Governor-in-Council to conduct the inquiry.

"Commission" means the Royal Commission on the *Ocean Ranger* Marine Disaster established pursuant to Order-in-Council PC 1982-819 and the Lieutenant Governor-in-Council's Commission dated the 16th day of March A.D. 1982.

"Governor-in-Council" means the Governor-in-Council of Canada.

"Inquiry" means that portion of the inquiry of the Commission contained in paragraph 1 of Order-in-Council PC 1982-819 and paragraph 1 of the Lieutenant Governor-in-Council's Commission dated the 16th day of March A.D. 1982.

"Order-in-Council" means the Order of the Governor-in-Council No. PC 1982-819 dated the 17th day of March A.D. 1982.

"Lieutenant Governor-in-Council" means the Lieutenant Governor-in-Council for the province cf Newfoundland.

"Technical Investigating Officer" means a person authorized and deputed to inquire into any matter within the scope of the Commission under the provisions of subsection (2) of section 11 of the Act.

NOTICE OF INQUIRY

4. (1) Notice of the inquiry shall be served upon the Owner, the Charterer and the Operator of the *Ocean Ranger* and upon any other person, corporation, Minister of the Crown or Crown Agency who, in the Commission's opinion, may have an interest in the inquiry.

(2) In addition to, or in lieu of the Notice of Inquiry provided for in subsection (1) of this section 4, Notice of the Inquiry may be given by publication of the same in the Canada Gazette, the Gazettes of each of the Provinces of Canada and in such Canadian and foreign newspapers or other publications as in the opinion of the Commission would be appropriate.

(3) A Notice of Inquiry shall set out the time and place appointed for the Inquiry and shall have attached thereto a copy of Order-in-Council PC 1982-819 and the Lieutenant Governor-in-Council's Commission dated the 16th day of March A.D. 1982.

RIGHT TO BE HEARD

5. (1) The following persons or their counsel shall have the right to be heard and to examine witnesses heard at public hearings of the Commission:

(a) Commission Counsel;

(b) Any person against whom a charge is made in the course of the Commission's investigation into the conduct of any person;

(c) Any person, in addition to the above persons, who in the Commission's opinion ought to be given such right and then upon such terms as the Chairman may direct.

(2) Any person wishing to be heard shall apply in writing to the Commission for the right to be heard and to examine witnesses heard at public hearings of the Commission, and shall state specifically his interest or interests and the extent of standing desired. Provided that the Commission is satisfied that standing is necessary for the protection of such interest or interests, the Chairman may grant standing upon such terms as the Chairman may direct.

(3) At the conclusion of the public hearings of the Commission any person, group or association will have the right at that time to make submissions to the Commission in writing, and, if the Chairman deems it necessary or expedient so to do, to make oral submissions following the filing of such written submissions.

(4) The Commission may in its discretion hold hearings in camera and the Chairman shall decide in the circumstances of that particular case who shall be permitted to attend, which counsel shall be permitted to attend and what conditions may be imposed upon any persons or counsel permitted to attend, all in the light of the law governing the inquiry.

(5) Persons having the right to be heard may apply to Commission Counsel to call any witness or witnesses and such witness may be called by Commission Counsel. Any such application shall contain the full name and address of the witness and a concise statement of why such a witness should be called to give evidence. Any witness so called shall be examined first by Commission Counsel and then, subject to the provisions of subsection (5) of section 7 of these Rules, by other persons having the right to be heard and to examine witnesses at public hearings of the Commission in the order designated by the Chairman.

COMMISSON COUNSEL

6. (1) Commission Counsel shall assist the Commission in the orderly conduct of the Inquiry and ensure that all relevant evidence is submitted to the Commission.

(2) At any public hearing any member of the public may request Commission Counsel, in writing, to ask a particular question of a witness and Commission Counsel may, in his discretion, ask such question.

(3) Commission Counsel shall prepare for the Commission's consideration in camera any charges which may be made against any person and upon being directed so to do by the Com-

mission give reasonable notice of the same to the person of the charge of misconduct alleged against him and to proceed thereafter in such manner as the Chairman directs and in accordance with the provisions of Section 12 and 13 of the Act.

INQUIRY PROCEDURE

7. (1) Prior to the commencement of public hearings for the purpose of hearing witnesses the Commission may hold procedural hearings for the purpose of determining what persons shall have the right to be heard and for the purpose of having Commission Counsel tender documentary or physical evidence which Commission Counsel determines should be tendered in advance of the public hearings for the convenience of the Commission or persons entitled to be heard.

(2) The Notice of Inquiry shall be read at the first public hearing of the Inquiry.

(3) Commission Counsel shall proceed first with the examination of witnesses on behalf of the Commission.

(4) Commission Counsel may examine, cross-examine or re-examine all witnesses.

(5) Other persons having the right to be heard and to examine witnesses at public hearings of the Commission may, in such order as the Chairman directs and subject to such terms as may have been imposed upon such right by the Chairman under the provisions of subsections 1(c) or 2 of section 5 of these Rules, examine, cross-examine or re-examine witnesses called by Commission Counsel.

PRESENCE OF INTERESTED PERSONS

8. At the time and place appointed for holding the Inquiry the Commission may proceed with the Inquiry whether or not persons entitled to be heard or their counsel are present.

ATTENDANCE OF WITNESSES

9. Where the Commission requires the attendance of any witness, either of its own motion or as a result of any application, the Notice to be served on the witness shall be in the form set out in Schedule 1.

PRODUCTION OF DOCUMENTS

10. (1) Where the Commission requires the production of any document by any person either of its motion or as a result of an application, notice to be served on that person shall be in the form set out in Schedule 2.

(2) Other persons having the right to be heard may apply to Commission Counsel to require the production of any document and Commission Counsel may require the production of such document. Any such application shall contain a complete description of the document requested, the name and address of the person from whom production of the document should be requested and a concise statement of why such document should be produced.

(3) Where an Order under subsection (1) of this section 10 is not complied with, the Commission may, in addition to any remedy, admit such other evidence as is available, whether hearsay or not, as evidence of the documents and things specified in the Order.

SERVICE OF DOCUMENTS

11. Any notice, summons or other document issued under these Rules may be served personally at the address of the person to be served, by certified post, or by such other method of service as the Chairman may direct.

EVIDENCE

12. (1) The Commission may admit as evidence Affidavits, Statutory Declarations, Rogatory Commissions and other evidence made or taken under the laws of Canada or any other country that may be applicable in any case in which the Commission considers it fit and proper to have such evidence presented, and whether such evidence is sworn or unsworn.

(2) Questions asked and documents and exhibits tendered as evidence in the course of the examination of witnesses called on behalf of the Commission shall not be open to objection merely on the ground that they do or may raise questions or issues that are not contained in or vary from the Terms of Reference contained in paragraph 1 of respectively, Order-in-Council PC 1982-819 and the Lieutenant Governor-in-Council's Commission dated March 16, 1982.

(3) Where documentary evidence or a witness is outside the jurisdiction of Canada or is otherwise not available for Commission hearings the Chairman or such person or persons as he may designate may be authorized to obtain such evidence in such manner as the Chairman may direct.

(4) Where possible the evidence of witness shall be taken under oath or solemn affirmation and witnessess shall be sworn or affirmed in the manner provided by the high courts having jurisdiction over the place where the evidence is taken.

(5) All evidence taken in any manner provided for by these Rules shall form a part of the record of the proceedings of the Commission.

13. (1) When the examination of all witnesses called by Commission Counsel has been concluded, other persons having the right to be heard and examine witnesses at public hearings of the Commission may adduce evidence relevant to their client's interests and such other evidence relevant to the subject matter of the Inquiry as the Chairman may by leave permit.

(2) Where any person's conduct is involved and that person is a person referred to in Section 12 or 13 of the Act, Commission Counsel shall:

(a) when the examination of all witnesses called on behalf of the Commission has been concluded, and,

(b) prior to any report made by the Commission against such person, inform the Commission of the issue upon which such person is entitled to be represented and heard.

SUBMISSIONS BY COUNSEL

14. (1) When all evidence has been adduced for the Inquiry, Commission Counsel and other persons entitled to be heard shall have the right to address the Commission viva voce in such order as the Chairman directs and Commission Counsel shall have the right to address the Commission last.

(2) The Chairman may direct that writ-

ten submission be made by counsel and other persons entitled to be heard in lieu of or in addition to their oral submissions.

THE CHAIRMAN

15. (1) The Chairman shall rule on any objections raised, determine all matters of procedure not provided for by these rules and, when in his discretion it is necessary or desirable for the purpose of fully discharging the duties of the Commission, may allow departures from these rules.

(2) The Chairman shall determine the admissibility of any evidence tendered at such time as he deems fit.

(3) The Chairman or any person designated by him may, in such a manner as the Chairman directs, take evidence in camera and in the absence of Commission Counsel or persons having the right to be heard and to examine witnesses at public hearings.

(4) The Chairman or any Commissioner or person designated by the Chairman to take evidence may take such evidence within or without Canada.

(5) Where by these Rules reference is made to a decision of the Commission, such decision of the Commission shall be enunciated by the Chairman.

QUORUM

16. A quorum for public hearings of the Commission shall be not less than four Commissioners.

ADJOURNMENTS

17. The Commission may adjourn its inquiry from time to time and from place to place.

AMENDMENTS

18. These rules may be amended from time to time by the Commission as it sees fit.

SCHEDULE I

(Subpoena ad testificandum)
Pursuant to Section 4 of The Inquiries Act

IN THE MATTER OF an Inquiry into the Loss of all Members of the Crew of the Semi-submersible self-propelled drill rig *Ocean Ranger* and of the *Ocean Ranger* on or about the 15th day of February, 1982, on the continental shelf off Newfoundland and Labrador.

ELIZABETH, THE SECOND, by the Grace of God of the United Kingdom, Canada, and Her other Realms and Territories, QUEEN, Head of the Commonwealth, Defender of the Faith.

TO: 1. ____________________
2. ____________________
3. ____________________
4. ____________________

GREETING:

We command you that all excuses ceasing, you and each of you do personally be and appear before the Commissioners appointed under The Inquiries Act to inquire into the above loss at the place of the Inquiry at in the City of St. John's in the Province of Newfoundland on the day of A.D., 1982, at o'clock in the noon to testify the truth according to your knowledge in an Inquiry being held by the Commissioners in the matter of the loss of the *Ocean Ranger* and its crew and hereof fail not at your peril.

Given under my hand at the City of St. John's in the Province of Newfoundland the day of A.D., 1982.

T. Alexander Hickman, Chief Justice,
CHAIRMAN OF THE COMMISSION

SCHEDULE II

(Subpoena duces tecum)
Pursuant to Section 4 of The Inquiries Act

IN THE MATTER OF an Inquiry into the Loss of all Members of the Crew of the Semi-submersible self-propelled drill rig *Ocean Ranger* and of the *Ocean Ranger* on or about the 15th day of February, 1982, on the continental shelf off Newfoundland and Labrador.

ELIZABETH, THE SECOND, by the Grace of God of the United Kingdom, Canada, and Her other Realms and Territories, QUEEN, Head of the Commonwealth, Defender of the Faith.

TO: 1. ____________________
2. ____________________
3. ____________________
4. ____________________

GREETING:

We command you that all excuses ceasing, you and each of you do personally be and appear before the Commissioners appointed under The Inquiries Act to inquire into the above loss at the place of the Inquiry at in the City of St. John's in the Province of Newfoundland on the day of A.D., 1982, at o'clock in the noon to testify the truth according to your knowledge in an Inquiry being held by the Commissioners in the matter of the loss of the *Ocean Ranger* and its crew and that you bring with you and then and there produce before the said Commissioners the following documents, viz:

____
____
____

and show all and singular those things which you know, or which the said paper writing doth import of, in or concerning the present inquiry now depending on our said Commissioners and hereof fail not at your peril

Given under my hand at the City of St. John's in the Province of Newfoundland the day of A.D., 1982.

T. Alexander Hickman, Chief Justice,
CHAIRMAN OF THE COMMISSION

COMMISSIONERS

Chief Justice T. Alexander Hickman, Chairman
The Honourable Gordon A. Winter, O.C., Vice Chairman
Fintan J. Aylward, Q.C.
Jan Furst, P.Eng.
M.O. Morgan, C.C.
N. Bruce Pardy, P.Eng.

COUNSEL

Leonard A. Martin, Q.C.
David B. Orsborn

COMMISSION SECRETARY

David M. Grenville

Item A-4

Royal Commission on the
Ocean Ranger Marine Disaster
Canada

Commission Royale sur le
Désastre Marin de l'*Ocean Ranger*
Newfoundland Terre Neuve

APPLICATIONS FOR STANDING

Persons wishing to apply for standing to be heard by the Royal Commission on the Ocean Ranger Marine Disaster are requested to contact the Commission on or before August 20, 1982, for information on practice and procedure and on the filing of a formal application. This present application refers only to standing in the Commission's investigations of the cause of the loss as set out in Section 1 of the Terms of Reference and not to those matters set out in Section 2 of the Terms of Reference. Copies of the Terms of Reference can be obtained on request.

Please direct all correspondence and queries to:

Royal Commission on the "OCEAN RANGER" Marine Disaster
P.O. Box 2400, Station "C", St. John's, Newfoundland A1C 6G3
Attention: Commission Secretary

Telephone: (709) 772-4319 Telex: 016-4720

Item A-5
List of Applicants with Standing

STATUS:

Commission Counsel	Leonard A. Martin, Q.C. David B. Orsborn

INTERESTED PARTIES WITH STANDING:

Counsel on behalf of ODECO Drilling of Canada Limited	John J. O'Neill, Q.C. George A. Frilot, III Tucker H. Couvillon, III Winston E. Rice James Shuey D. Richard Robbins
Counsel on behalf of Mobil Oil Canada Limited	Michael F. Harrington Janet M. Henley Andrews
Counsel on behalf of the American Bureau of Shipping	Thomas Coyne David L. Russell, Q.C.
Counsel on behalf of the Government of Newfoundland	James L. Thistle
Counsel on behalf of Seaforth Maritime Limited and Seabase Nova Scotia Limited	Kenneth A. MacInnis
Counsel on behalf of the Government of Canada	Norman J. Whalen Dana Lenehan
Counsel on behalf of the Master, Officers and Crew, *Seaforth Highlander*	Donald A. Kerr, Q.C.
Counsel on behalf of Watercraft America Inc.	John M. Green
Counsel on behalf of Next of Kin:	Leo D. Barry, Q.C. Raymond J. Halley, Q.C. A. Douglas Moores, Q.C. Claude Sheppard, Jr. John F. Roil Robert B. Andrews David F. Hurley W. Gerard O'Dea Bernard M. Coffey John J. Harris Gillian D. Butler A. Dianne Fraser John A. Bruce

OFFICIAL OBSERVERS:

The *Ocean Ranger* Families Foundation
The Workers' Compensation Board of Newfoundland & Labrador
The Newfoundland & Labrador Federation of Labour

Item A-6

Royal Commission on the *Ocean Ranger* Marine Disaster
Canada

Commission Royale sur le Désastre Marin de l'*Ocean Ranger*
Newfoundland Terre-Neuve

NOTICE OF INQUIRY

The Royal Commission on the Ocean Ranger Marine Disaster will commence public hearings at 10:00 a.m. on October 25,1982 in the Canon Stirling Auditorium, Church of St. Mary the Virgin on Craigmillar Avenue in the City of St. John's in the Province of Newfoundland and Labrador.

This Notice of Inquiry is issued pursuant to the Ocean Ranger Marine Disaster Inquiry Rules.

Copies of the Terms of Reference and of the Inquiry Rules applying to that portion of the inquiry contained in paragraph one of those terms of reference, may be obtained by application to the Secretary:

David M. Grenville
Commission Secretary
Royal Commission on the Ocean Ranger Marine Disaster
P. O. Box 2400, Station "C"
St. John's, Newfoundland
A1C 6G3

Item A-7
List of Witnesses Testifying During Part I Hearings

TRANSCRIPT	DATE 1982	NAME	CORPORATE AFFILIATION (FEBRUARY 1982)
Volume 1	October 25	MILNE, William	Professor of Engineering, Memorial University of Newfoundland
Volume 2	October 26	BORUM, John F.	Vice-President, American Bureau of Shipping
Volume 3 to Volume 5	October 27 to October 29	DILKS, Geoffrey	Master, *Ocean Ranger*, Ocean Drilling & Exploration Company
Volume 5 & Volume 6	October 29 & November 02	BAMBER, Peter John	Former Master, *Ocean Ranger*, Marine Superintendent, Ocean Drilling & Exploration Company
Volume 7	November 03	SKAUG, Erlend	Former Master, *Ocean Ranger*, (Hiroshima/Alaska), Fearnley & Eger A/S
Volume 8	November 04	LIMA, Ordin	Former Master, *Ocean Ranger*, During Transits, Ocean Drilling & Exploration Company
Volume 8	November 04	SOERUM, Bjorn	Former Marine Engineer, *Ocean Ranger*, Fearnley & Eger A/S
Volume 9	November 05	GRANGER, George	Electrician, *Ocean Ranger*, Ocean Drilling & Exploration Company
Volume 10	November 08	WIKLUND, Svein	Former Electrician, *Ocean Ranger*, Fearnley & Eger A/S
Volume 10 to Volume 11	November 08 to November 09	MAJOR, Lloyd	Medic & Standby Radio Operator, *Ocean Ranger*, ODECO Drilling of Canada Limited
Volume 11	November 09	SHAW, Brian Walter	Former Radio Operator, *Ocean Ranger*, Service Engineer, Government of Canada
Volume 12	November 10	WILCOX, Ronald John	Department of Communications, Government of Canada
Volume 12	November 10	JANES, John Patrick	Department of Communications, Government of Canada
Volume 12	November 10	ROMANSKY, Stephen	East Coast Operations Manager, Mobil Oil Canada Limited
Volume 13	November 15	SPELLACY, Richard	President & Chief Executive Officer, Crosbie Offshore Services Limited
Volume 14	November 16	GOSSE, Raymond Gordon	Assistant Deputy Minister, Newfoundland & Labrador Petroleum Directorate

Volume 14 to Volume 15	November 16 to November 17	BRANDON, Lionel Victor	Director General, Engineering Branch, Canada Oil & Gas Lands Administration
Volume 15 to Volume 16	November 17 to November 18	HEWSON, Michael David	Manager, Environmental Forecasting Group, NORDCO Limited
Volume 16	November 18	PORTER, Stuart	Supervising Forecaster, Atmospheric Environmental Service, Gander, Government of Canada
Volume 16	November 18	SWAIL, Val	Climatologist, Atmospheric Environmental Service, Toronto, Government of Canada
Volume 16 to Volume 17	November 18 to November 19	WILSON, John Ronald	Director, Marine Environmental Data Service, Fisheries & Oceans, Ottawa, Government of Canada
Volume 18	December 06	Schedule Change	
Volume 19 to Volume 20	December 07 to December 08	HIMES, Clifford	Ballast Control Operator, *Ocean Ranger*, Ocean Drilling & Exploration Company
Volume 20 to Volume 21	December 08 to December 09	SIMPSON, Delmar	Electronic Technician, *Ocean Ranger* Ocean Drilling & Exploration Company
Volume 21 to Volume 22	December 09 to December 10	WILSON, John	Principal Surveyor, American Bureau of Shipping
Volume 22	December 10	ROMANSKY, Stephen	East Coast Operations Manager, Mobil Oil Canada Limited
Volume 23 to Volume 24	December 13 to December 14	JENNINGS, Frank	Former Ballast Control Operator, *Ocean Ranger*, Ocean Drilling & Exploration Company
Volume 24	December 14	FREEMAN, Geoffrey	Instructor, Petroleum Technology, College of Trades & Technology Former Inspector, Canada Oil & Gas Lands Administration
Volume 24	December 14	STRONG, Derek	Inspector, Canada Oil & Gas Lands Administration, Government of Canada
Volume 24	December 14	BURSEY, Maxwell	Director of Claims, Workers' Compensation Board
Volume 25	December 15	MCCANN, Ed P.	Director of Employment Services, Government of Newfoundland & Labrador
Volume 25	December 15	ENGLISH, William Joseph	Former Weather Observer, *Ocean Ranger*, MacLaren PlanSearch (FENCO)

TRANSCRIPT	DATE 1983	NAME	CORPORATE AFFILIATION (FEBRUARY 1982)
Volume 26 to Volume 27	March 08 to March 09	PORTER, Bruce	Ballast Control Operator, *Ocean Ranger*, ODECO Drilling of Canada Limited
Volume 27 to Volume 29	March 09 to March 11	NEHRING, Karl	Former Master, *Ocean Ranger*, Ocean Drilling & Exploration Company
Volume 29	March 11	COUNTS, Jimmy Earl	Drilling Superintendent, *Ocean Ranger*, Ocean Drilling & Exploration Company
Volume 30	March 14	TROXELL, George H., Jr.	Manager, Drilling Operations, Ocean Drilling & Exploration Company
Volume 31 to Volume 32	March 15 to March 16	COUNTS, Jimmy Earl	Drilling Superintendent, *Ocean Ranger*, Ocean Drilling & Exploration Company
Volume 32 to Volume 34	March 16 to March 18	GRAHAM, Mervin William	Area Drilling Superintendent, Grand Banks, Mobil Oil Canada Limited
Volume 35	March 21	KING, Baxter	Radio Operator, *SEDCO 706*, SEDCO 706 Drilling Company Limited
Volume 36	March 23	HIGDON, Jerry Woodrow	Second Mate, *MV Seaforth Highlander*, Seaforth Maritime Limited
Volume 37	March 24	JORGENSEN, Rolf	First Mate, *MV Seaforth Highlander*, Seaforth Maritime Limited
Volume 38	March 25	LIDSTONE, Kenneth Wayne	Seaman, *MV Seaforth Highlander*, Seaforth Maritime Limited
Volume 38	March 25	REES, Eric Norman	Seaman, *MV Seaforth Highlander*, Seaforth Maritime Limited
Volume 38	March 25	WOOLRIDGE, Wycliff Bert	Seaman, *MV Seaforth Highlander*, Seaforth Maritime Limited
Volume 38	March 25	CHAYTOR, Dennis Gerard	Seaman, *MV Seaforth Highlander*, Seaforth Maritime Limited
Volume 38	March 25	THOMPSON, Wayne	Cook, *MV Seaforth Highlander*, Seaforth Maritime Limited
Volume 39 to Volume 40	March 28 to March 29	DUNCAN, Ronald Stewart	Master Mariner, *MV Seaforth Highlander*, Seaforth Maritime Limited
Volume 40	March 29	TAVENOR, Christine	Radio Operator, St. John's, Mobil Oil Canada Limited
Volume 40 to Volume 41	March 29 to March 30	FLYNN, Richard	Radio Operator, St. John's, Mobil Oil Canada Limited

Volume 41 to Volume 42	March 30 to March 31	KING, Donald	Barge Engineer, *SEDCO 706*, SEDCO 706 Drilling Company Limited
Volume 42	March 31	LOVELL, Kenneth	Senior Drilling Foreman, *Zapata Ugland*, Mobil Oil Canada Limited
Volume 43	April 05	SENKOE, Keith	Drilling Foreman, *SEDCO 706*, Mobil Oil Canada Limited
Volume 44	April 06	EBY, James	Chief Engineer, *MV Boltentor*, Crosbie Offshore Services Limited
Volume 44	April 06	GUPTILL, Clinton	First Mate, *MV Boltentor*, Crosbie Offshore Services Limited
Volume 45	April 07	ALLINGHAM, Baxter	Master, *MV Nordertor*, Crosbie Offshore Services Limited
Volume 46	May 16	GERNANDT, Kelvin (Blondie)	Operations Manager, St. John's, Ocean Drilling & Exploration Company
Volume 47	May 17	URSULAK, William John	Drilling Foreman, *SEDCO 706*, Mobil Oil Canada Limited
Volume 47	May 17	HATCHER, Fred	Watchstander/Ballast Control Operator, *SEDCO 706*, SEDCO 706 Drilling Company Limited
Volume 48	May 18	BOURQUE, Leo	Watchstander/Ballast Control Operator, *SEDCO 706*, SEDCO 706 Drilling Company Limited
Volume 48 to Volume 49	May 18 to May 19	FRASER, Rod	Drilling Foreman, *SEDCO 706*, Mobil Oil Canada Limited
Volume 49	May 19	DAVISON, James	Master, *MV Boltentor*, Crosbie Offshore Services Limited
Volume 50	May 20	MARTIN, Malcolm Alan	Second Mate, *MV Boltentor*, Crosbie Offshore Services Limited
Volume 50	May 20	KANE, Thomas	Deckhand, *MV Boltentor*, Crosbie Offshore Services Limited
Volume 51	May 24	MYDLAND, Jan Arthur	Master, *Zapata Ugland*, Zapata Drilling Company
Volume 51	May 24	POWER, William	Radio Operator, Ministry of Transport, Government of Canada
Volume 51 to Volume 53	May 24 to May 26	BEATTIE, Ken	Logistics Supervisor, Hibernia Area, Mobil Oil Canada Limited
Volume 53	May 26	HUTCHINGS, Bruce Reginald	Co-pilot, Universal Helicopters, St. John's
Volume 54	May 27	PREUS, Rudolph Victor	Aircraft Commander, Search & Rescue, 103 Rescue Unit, Gander

Volume 54	May 27	CLARKE, George Michael	Aircraft Commander, Search & Rescue, 103 Rescue Unit, Gander
Volume 54	May 27	BROWN, Randall Keith	Search & Rescue Technician, 103 Rescue Unit, Gander
Volume 55	May 30	BARNES, Albert Grenville	Marine Co-ordinator, Search & Rescue Emergency Centre, St. John's
Volume 55	May 30	REHSE, Fred Major	Commanding Officer, Search and Rescue, 103 Rescue Unit, Gander
Volume 55	May 30	PIKE, Dr. Eric	Forensic Pathologist, General Hospital Health Sciences Centre
Volume 56	May 31	LEONARD, Bernard Michael	Rescue Officer, Canadian Coast Guard, Search & Rescue Emergency Centre, St. John's
Volume 56	May 31	MAWHINNEY, John	Duty (Air)Controller, Rescue Co-ordination Centre, Halifax
Volume 56	May 31	GILLIS, Colin	Commanding Officer, Rescue Co-ordination Centre, Halifax
Volume 57	June 01	FAHEY, Patrick Joseph	Second Mate, *MV Nordertor*, Crosbie Offshore Services
Volume 57	June 01	GALLAGHER, Robert	Technical Co-ordinator, Royal Air Force Special Exchange Assignment Greenwood, Nova Scotia
Volume 57	June 01	RUELOKKE, Max	Vice President & General Manager, Hydrospace Marine Services
Volume 58	June 02	Schedule Change	
Volume 59	July 19	OLSEN, Mikkjal	Master, Faroese Fishing Vessel *Sigurfari* Operated by Hewson & Olsen, Faroe Islands
Volume 60	September 12	MARKLE, Robert Louis	Chief, Survival Systems Branch, United States Coast Guard, Washington, D.C.
Volume 61	September 13	VERMIJ, Maximillian	Electrical-Mechanical Analysis Specialist, Aviation Safety Bureau, Transport Canada
Volume 62	September 14	BAIKOWITZ, Harry	President, Technitrol Canada Limited
Volume 62 to Volume 64	September 14 to September 16	VERMIJ, Maximillian	Electrical-Mechanical Analysis Specialist, Aviation Safety Bureau, Transport Canada

Volume 65 to Volume 66	November 21 to November 22	McDONALD, Hamish	Manager, Maritime Rescue Section, Robert Gordon Institute of Technology Offshore Survival Centre, Stonehaven, Scotland
Volume 66	November 22	WRIGHT, Keith	Chief Engineer, *MV Seaforth Highlander*, Seaforth Maritime Limited
Volume 66	November 22	SCAMMEL, Derek	Third Engineer, *MV Seaforth Highlander*, Seaforth Maritime Limited
Volume 66 to Volume 67	November 22 to November 23	CADD, Roger	Chartering Manager, Seaforth Fednav
Volume 67	November 23	SNOW, Dr. Wayne John	Shore-based Medical Advisor To *Ocean Ranger* crew members
Volume 67	November 23	SKILLMAN, Mark Robert	Senior Ships Surveyor, Lloyd's Register of Shipping, London
Volume 68	November 24	ATKINSON, Frederick Harper	Head, Offshore Services Group, Lloyd's Register of Shipping, London
Volume 68	November 24	KAPRAL, Peter	Drilling Foreman, Mobil Oil Canada Limited
Volume 68	November 24	DAVIES, Brinley Moore	Chief, Communications & Computer Engineering Division, Canadian Coast Guard
Volume 68	November 24	ASHFORD, Angus	First Mate, *MV Cape Fox*, National Sea Products Limited
Volume 69	November 28	STEIMLER, Gustav Adolf	Director, Norwegian Sea Rescue Association, Oslo, Norway
Volume 69	November 28	STEVENSON, Ronald	Manager, Liferaft Department, IMP Group Limited
Volume 69	November 28	O'DONNELL, James Joseph	Inspector, Liferafts, IMP Group Limited
Volume 70	November 29	BERTHIER, Joseph Edgar (Wayne)	Former Safety Engineer, ODECO Drilling of Canada Limited
Volume 70	November 29	TURNER, Daniel	Seaman, *MV Boltentor*, Crosbie Offshore Services Limited
Volume 71	November 30	HALFWEEG, Nan	Managing Director, Wijsmuller Salvage B.V.
Volume 71	November 30	GREER, John	Director, Emergency Measures Organization, Government of Newfoundland & Labrador
Volume 72	December 01	LEGER, Donald R.	Former Senior Toolpusher, *Ocean Ranger*, Ocean Drilling & Exploration Company

TRANSCRIPT	DATE 1984	NAME	CORPORATE AFFILIATION (FEBRUARY 1982)
Volume 72A	January 30	Schedule Change	
Volume 73 to Volume 74 & Volume 76 (pp. 12251a - 12251c)	February 27 to February 28 & March 01	LOOMIS, Ralph W.	Supervisor of Mechanical & Drilling Engineering, ODECO Engineers Inc.
Volume 75	February 29	ADAMS, Michael Morris	Supervisor, Naval Architects, ODECO Engineers Inc.
Volume 75 to Volume 76	February 29 to March 01	PETTY, Dr. Terry Don	President, ODECO Engineers Inc.
Volume 77	March 02	VERMIJ, Maximillian	Electrical-Mechanical Analysis Specialist, Aviation Safety Bureau, Transport Canada
Volume 78 to Volume 82 & Volume 83 to Volume 85	March 05 to March 09 & March 12 to March 14	CORLETT, Dr. Ewan Christian	Naval Architect, Ship Designer & Marine Consultant, Burness, Corlett & Partners (IOM) Limited
SUMMATIONS			
Volume 86	March 20	MARTIN, Leonard A., Q.C.	Commission Counsel, Royal Commission on the *Ocean Ranger* Marine Disaster
Volume 86	March 20	WHALEN, Norman J.	Counsel, Government of Canada
Volume 86	March 20	THISTLE, James L.	Counsel, Government of Newfoundland & Labrador
Volume 86	March 20	COYNE, Thomas	Counsel, American Bureau of Shipping
Volume 86 to Volume 87	March 20 to March 21	MACINNIS, Kenneth A.	Counsel, Seaforth Maritime & Seabase Nova Scotia Limited
Volume 87	March 21	HARRINGTON, Michael F.	Counsel, Mobil Oil Canada Limited
Volume 87 to Volume 88	March 21 to March 22	FRILOT, George A., III	Counsel, ODECO Drilling of Canada Limited
Volume 88	March 22	ORSBORN, David B.	Associate Commission Counsel, Royal Commission on the *Ocean Ranger* Marine Disaster

Item A-8
Alphabetical List of Witnesses

NAME	TRANSCRIPT	DATE
ADAMS, Michael Morris	Volume 75	February 29, 1984
ALLINGHAM, Baxter	Volume 45	April 07, 1983
ASHFORD, Angus	Volume 68	November 24, 1983
ATKINSON, Frederick Harper	Volume 68	November 24, 1983
BAIKOWITZ, Harry	Volume 62	September 14, 1983
BAMBER, Peter John	Volume 5 & Volume 6	October 29, 1982 & November 02, 1982
BARNES, Albert Grenville	Volume 55	May 30, 1983
BEATTIE, Ken	Volume 51 to Volume 53	May 24, 1983 to May 26, 1983
BERTHIER, Joseph Edgar (Wayne)	Volume 70	November 29, 1983
BORUM, John F.	Volume 2	October 26, 1982
BOURQUE, Leo	Volume 48	May 18, 1983
BRANDON, Lionel Victor	Volume 14 to Volume 15	November 16, 1982 to November 17, 1982
BROWN, Randall Keith	Volume 54	May 27, 1983
BURSEY, Maxwell	Volume 24	December 14, 1982
CADD, Roger	Volume 66 to Volume 67	November 22, 1983 to November 23, 1983
CHAYTOR, Dennis Gerard	Volume 38	March 25, 1983
CLARKE, George Michael	Volume 54	May 27, 1983
CORLETT, Dr. Ewan Christian	Volume 78 to Volume 82 & Volume 83 to Volume 85	March 05, 1984 to March 09, 1984 & March 12, 1984 to March 14, 1984
COUNTS, Jimmy Earl	Volume 29 & Volume 31 to Volume 32	March 11, 1983 & March 15, 1983 to March 16, 1983

DAVISON, James	Volume 49	May 19, 1983
DAVIES, Brinley Moore	Volume 68	November 24, 1983
DILKS, Geoffrey	Volume 3 to Volume 5	October 27, 1982 to October 29, 1982
DUNCAN, Ronald Stewart	Volume 39 to Volume 40	March 28, 1983 to March 29, 1983
EBY, James	Volume 44	April 06, 1983
ENGLISH, William Joseph	Volume 25	December 15, 1982
FAHEY, Patrick Joseph	Volume 57	June 01, 1983
FLYNN, Richard	Volume 40 to Volume 41	March 29, 1983 to March 30, 1983
FRASER, Rod	Volume 48 to Volume 49	May 18, 1983 to May 19, 1983
FREEMAN, Geoffrey	Volume 24	December 14, 1982
GALLAGHER, Robert	Volume 57	June 01, 1983
GERNANDT, Kelvin (Blondie)	Volume 46	May 16, 1983
GILLIS, Colin	Volume 56	May 31, 1983
GOSSE, Raymond Gordon	Volume 14	November 16, 1982
GRAHAM, Mervin William	Volume 32 to Volume 34	March 16, 1983 to March 18, 1983
GRANGER, George	Volume 9	November 05, 1982
GREER, John	Volume 71	November 30, 1983
GUPTILL, Clinton	Volume 44	April 06, 1983
HALFWEEG, Ivan	Volume 71	November 30, 1983
HATCHER, Fred	Volume 47	May 17, 1983
HEWSON, Michael David	Volume 15 to Volume 16	November 17, 1982 to November 18, 1982
HIGDON, Jerry Woodrow	Volume 36	March 23, 1983
HIMES, Clifford	Volume 19 to Volume 20	December 07, 1982 to December 08, 1982

HUTCHINGS, Bruce Reginald	Volume 53	May 26, 1983
JANES, John Patrick	Volume 12	November 10, 1982
JENNINGS, Frank	Volume 23 to Volume 24	December 13, 1982 to December 14, 1982
JORGENSEN, Rolf	Volume 37	March 24, 1983
KANE, Thomas	Volume 50	May 20, 1983
KAPRAL, Peter	Volume 68	November 24, 1983
KING, Baxter	Volume 35	March 21, 1983
KING, Donald	Volume 41 to Volume 42	March 30, 1983 to March 31, 1983
LEGER, Donald R.	Volume 72	December 01, 1983
LEONARD, Bernard Michael	Volume 56	May 31, 1983
LIDSTONE, Kenneth Wayne	Volume 38	March 25, 1983
LIMA, Ordin	Volume 8	November 04, 1982
LOOMIS, Ralph W.	Volume 73 to Volume 74 & Volume 76 (pp. 12251a -12251c)	February 27, 1984 to February 28, 1984 & March 01, 1984
LOVELL, Kenneth	Volume 42	March 31, 1983
MAJOR, Lloyd	Volume 10 to Volume 11	November 08, 1982 to November 09, 1982
MARKLE, Robert Louis	Volume 60	September 12, 1983
MARTIN, Malcolm Alan	Volume 50	May 20, 1983
MCCANN, Ed P.	Volume 25	December 15, 1982
MCDONALD, Hamish	Volume 65 to Volume 66	November 21, 1983 to November 22, 1983
MAWHINNEY, John	Volume 56	May 31, 1983
MILNE, William	Volume 1	October 25, 1982
MYDLAND, Jan Arthur	Volume 51	May 24, 1983

NEHRING, Karl	Volume 27 to Volume 29	March 09, 1983 to March 11, 1983
O'DONNELL, James Joseph	Volume 69	November 28, 1983
OLSEN, Mikkjal	Volume 59	July 19, 1983
PETTY, Dr. Terry Don	Volume 75 to Volume 76	February 29, 1984 to March 01, 1984
PIKE, Dr. Eric	Volume 55	May 30, 1983
PORTER, Bruce	Volume 26 to Volume 27	March 08, 1983 to March 09, 1983
PORTER, Stuart	Volume 16	November 18, 1982
POWER, William	Volume 51	May 24, 1983
PREUS, Rudolph Victor	Volume 54	May 27, 1983
REES, Eric Norman	Volume 38	March 25, 1983
REHSE, Major Fred	Volume 55	May 30, 1983
ROMANSKY, Stephen	Volume 12 & Volume 22	November 10, 1982 & December 10, 1982
RUELOKKE, Max	Volume 57	June 01, 1983
SCAMMEL, Derek	Volume 66	November 22, 1983
SENKOE, Keith	Volume 43	April 05, 1983
SHAW, Brian Walter	Volume 11	November 09, 1982
SIMPSON, Delmar	Volume 20 to Volume 21	December 08, 1982 to December 09, 1982
SKAUG, Erlend	Volume 7	November 03, 1982
SKILLMAN, Mark Robert	Volume 67	November 23, 1983
SNOW, Dr. Wayne John	Volume 67	November 23, 1983
SOERUM, Bjorn	Volume 8	November 04, 1982
SPELLACY, Richard	Volume 13	November 15, 1982
STEIMLER, Gustav Adolf	Volume 69	November 28, 1983
STEVENSON, Ronald	Volume 69	November 28, 1983
STRONG, Derek	Volume 24	December 14, 1982

SWAIL, Val	Volume 16	November 18, 1982
TAVENOR, Christine	Volume 40	March 29, 1983
THOMPSON, Wayne	Volume 38	March 25, 1983
TROXELL, George H., Jr.	Volume 30	March 14, 1983
TURNER, Daniel	Volume 70	November 29, 1983
URSULAK, William John	Volume 47	May 17, 1983
VERMIJ, Maximillian	Volume 61 to Volume 64 & Volume 77	September 13, 1983 to September 16, 1983 & March 02, 1984
WIKLUND, Svein	Volume 10	November 08, 1982
WILCOX, Ronald John	Volume 12	November 10, 1982
WILSON, John	Volume 21 to Volume 22	December 09, 1982 to December 10, 1982
WILSON, John Ronald	Volume 16 to Volume 17	November 18, 1982 to November 19, 1982
WOOLRIDGE, Wycliff Bert	Volume 38	March 25, 1983
WRIGHT, Keith	Volume 66	November 22, 1983

SUMMATIONS

COYNE, Thomas	Volume 86	March 20, 1984
FRILOT, George A., III	Volume 87 to Volume 88	March 21, 1984 to March 22, 1984
HARRINGTON, Michael F.	Volume 87	March 21, 1984
MACINNIS, Kenneth A.	Volume 86 to Volume 87	March 20, 1984 to March 21, 1984
MARTIN, Leonard A., Q.C.	Volume 86	March 20, 1984
ORSBORN, David B.	Volume 88	March 22, 1984
THISTLE, James L.	Volume 86	March 20, 1984
WHALEN, Norman J.	Volume 86	March 20, 1984

Item A-9
List of Exhibits Introduced During Part I Hearings

1 The Government of Canada Order in Council, PC 1982-819, March 17, 1982.

2 The Government of Newfoundland and Labrador Order in Council, March 16, 1982.

3 *Ocean Ranger* Data Profile issued by ODECO Engineers, Inc.

4 Certificate of Registry issued at New Orleans, Louisiana, by the United States Coast Guard, August 5, 1980.

5 Certificate of Inspection completed and issued at Providence, Rhode Island, by the United States Coast Guard, December 27, 1979.

6 Certificate of Cargo Ship Safety Equipment issued at New York, by the United States Coast Guard, December 27, 1980.

7 International Load Line Certificate issued at New York, by the American Bureau of Shipping, on behalf of United States Coast Guard, October 30, 1981.

8 Cargo Ship Safety Construction Certificate issued at New York, by the American Bureau of Shipping, on behalf of United States Coast Guard, April 28, 1980.

9 Cargo Ship Safety Radiotelegraphy Certificate issued at St. John's, Newfoundland, by the American Bureau of Shipping, under the authority of the Government of Canada, April 16, 1981.

10 Certificate of Annual Examination of Gear issued at St. John's, Newfoundland, by the American Bureau of Shipping, June 16, 1981.

11 Builder's Certificate issued by Mitsubishi Heavy Industries, Limited, Tokyo, Japan, May 28, 1976.

12 Certificate of Admeasurement issued by the United States Coast Guard, at New Orleans, Louisiana, December 21, 1979 and at Philadelphia, Pennsylvania, June 30, 1980.

13 Designation of Home Port of Vessel issued at New Orleans, Louisiana, by the United States Coast Guard, June 26, 1980.

14 Oaths of Registry, Licence of Vessel, issued at New Orleans, Louisiana, by the United States Coast Guard, June 24, 1980.

15 Sea-Jay Elliot Inflatable Life Rafts Certificate of Service, issued by IMP Group Limited, May-July, 1981. Serial Nos. 20, 710-714.

15A Sea-Jay Elliot Inflatable Life Rafts Certificate of Service, issued by IMP Group Limited, April-July, 1981. Serial Nos. 715 to 718.

15B Descriptive Literature for Sea-Jay Elliot Liferafts.

16 *Ocean Ranger* Emergency Procedures issued by ODECO Drilling of Canada Limited.

17 Emergency Muster List, Fire or Abandon Ship Procedure for the *Ocean Ranger*.

18 *SEDCO 706*, Radio Logs & Weather, February 14-17, 1982.

19 *SEDCO 706*, Barge Control Log, February 1-20, 1982.

19A Typed Transcript of Exhibit 19, *SEDCO 706* Barge Control Log, February 14-15, 1982.

20 *SEDCO 706*, Barge Control Sheets, February 1-16, 1982.

21 Mobil Base Radio Logs for February 9-17, 1982.

21A Typed Transcript of Exhibit 21, Mobil Base Radio Logs for February 9-17, 1982.

22 Canadian Coast Guard Radio Log, St. John's, February 15-21, 1982.

23 Universal Helicopter Dispatcher's Log, February 15, 1982.

24 *Ocean Ranger* P.M. Status Reports to ODECO Drilling of Canada Limited, St. John's, February 1-14, 1982.

25 United States Coast Guard Informal Inspection Report by Lieutenant Commander Purtell, November 2, 1981.

26 *MV Nordertor* Radio Log, February 5-15, 1982.

26A Typed Transcript of Exhibit 26, *MV Nordertor* Radio Log, February 14-15, 1982.

27 ODECO Drilling of Canada Limited and Mobil Oil Canada Limited, Drilling Agreement, February 28, 1980, and October 16th, 1981, Extension.

28 Marisat Service Billing Record, February 1-15, 1982 – *Ocean Ranger*; February 1-16, 1982 – *SEDCO 706*.

29 Marisat Service Billing Record, January 15 – February 16, 1982 – *Ocean Ranger*.

30 Operational History of the *Ocean Ranger*, June 30, 1976 – February 14, 1982.

31 Mobil Oil Canada Limited Dispatchers Log, February 13-17, 1982.

32 *MV Nordertor* Deck Log, February 15, 1982.

32A Typed Transcript of Exhibit 32, *MV Nordertor* Deck Log, February 15, 1982.

33 Annual Class Survey issued by American Bureau of Shipping, June 17, 1981.

34 *Ocean Ranger* Weekly Stability Report, February 1, 1982.

34A *Ocean Ranger* Weekly Stability Report, February 11, 1982.

34B *Ocean Ranger* Drilling Report, February 10, 1982.

34C *Ocean Ranger* Stability Report, February 9, 1982.

35 Particulars of Watercraft Lifeboat, Rescue Boat & Davits.

36 Watercraft Lifeboat Brochures by Watercraft America Limited.

37 Assembly Diagram of Watercraft Lifeboat Davit.

38 Norwegian Certificates for Lifeboat Equipment issued by A/S Nor Davit, Bergen, and the manufacturers, according to regulations by Norwegian Maritime Directorate.

39 Anchoring Report, Hibernia Field Block #J-34, November 29, 1981.

40 Tuktoyaktuk Radio Message received from *Ocean Ranger* at 0442 Zulu (1:12 NST), February 14, 1982.

41 Final Identification List of *Ocean Ranger* On Duty Employees; including addresses, family contacts, etc.

42 *MV Boltentor* Deck Log, February 14-22, 1982.

42A Typed Transcript of Exhibit 42, *MV Boltentor* Deck Log, February 14-15, 1982.

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44 Rescue Co-ordination Centre "B" Stand Log, February 15-17, 1982.

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63 Canadian Forces Metoc Centre Wave Analysis, February 10-16, 1982.

64 Synoptic Reports prepared by Atmospheric Environment Centre, Gander for February 11-16, 1982.

65 *Ocean Ranger* Quarters General Arrangement, 2nd and 3rd Floors.

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67 Mobil Oil Canada Limited Contingency Plans & Emergency Procedures, August 1980.

68 List of Contractors to *Zapata Ugland, SEDCO 706* and *Ocean Ranger*.

69 Maps of Hibernia Well Sites provided by Newfoundland and Labrador Petroleum Directorate.

70 *Ocean Ranger* Mooring Pattern provided by Newfoundland and Labrador Petroleum Directorate.

71 St. John's Coast Guard Radio Communications with *Ocean Ranger* for January 1 – February 13, 1982.

72 St. John's Coast Guard Radio (VON) Log, February 15, 1982.

73 Installation of 58-Man Watercraft Lifeboat Arrangement, April 1, 1980.

74 Atlantic Weather Centre Six Hour Surface Analysis, February 11-17, 1982.

74A Twenty-seven Enhanced Drawings of *Ocean Ranger*, redrafted from as-built plans, including:
- General arrangement,
- Control room layout,
- Safety equipment.

74B *Ocean Ranger* as-built plans:
Arrangement of Pressure Gauge and Alarm Lamp – Drawing No. NMA 298-1-3B
Mimic Diagram of Control Face (Port Hull) – Drawing No. NMA 298-1-2
Mimic Diagram of Control Face (Starboard Hull) – Drawing No. NMA 298-1-1
Slides No. 070, 071, 072, respectively.

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Report on Main Propulsion Internal Combustion Engines;
Report on Electrical Propulsion Machinery;
Supplementary Report on Machinery, Pumps and Piping;
Report on Ships Service Electrical Equipment;
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Report of Annual Load Line Inspection	S13971	December 2, 1976
Load Line Certificate	61-30,895	May 5, 1977
Report on Annual Load Line Inspection	SF25645	June 21, 1977
Annual Survey of Hull and Machinery	SF 25644	June 21, 1977
Report of Annual Load Line Inspection	S15572	May 26, 1978
Underwater Survey, Seward, Alaska	S15571	October 24, 1978
Report on Propellor Damage	S15573	October 24, 1978
Report on Boat Bumper	VA7476	January 13, 1979
Report on Boat Damage	VA7728	March 6, 1979
Survey Report and Cargo Ship Safety Construction Certificate	VA7687	July 5, 1979
Report of Annual Load Line Inspection	VA7729	July 5, 1979
Report of Annual Load Line Inspection	PA4720	April 8, 1980
Survey Report and Cargo Ship Safety Construction Certificate	PA4724	April 8, 1980
Underwater Survey, Wilmington Canyon, Atlantic City, New Jersey	PA4936	April 8, 1980
Report of Annual Load Line Inspection	2915	June 17, 1981

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2) American Bureau of Shipping to ODECO Engineers Inc., April 13, 1977
3) ODECO Engineers Inc. to American Bureau of Shipping, November 9, 1977.

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1) United States Coast Guard to Ocean Drilling & Exploration Company, December 13, 1979
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93 *Ocean Ranger* Photographs Numbers 1-34 presented by Captain Erlend Skaug, former Master, *Ocean Ranger*.

94 Ballast Control Console Drawings No. P-3113, thirty-one pages including cover.

95 Photo: Radio Room, *Ocean Ranger* presented by Lloyd Major, Radio Operator, *Ocean Ranger*.

96 Certificate of Lifeboat Instruction issued to Lloyd Major, Radio Operator, by Karl Nehring, former Master, *Ocean Ranger*.

97 Curriculum Vitae, Lloyd Major, Radio Operator, *Ocean Ranger*.

98 Photo: MARISAT Radio on *Ocean Ranger* presented by Lloyd Major, Radio Operator.

99 Department of Communications, Correspondence relating to Inspection and Certification of *Ocean Ranger* Radio Equipment, April 1981.

100 "A Guide to Marine Radiotelephone Operation", issued under authority of Department of Communications, Atlantic Region, Canada.

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102 Contracts between Crosbie Enterprises and Mobil Oil Canada Limited for services of Supply Vessels *Boltentor* and *Nordertor.*

103A Rescue Equipment onboard six Crosbie Offshore Supply Vessels as of August 1982.

103B Radar Equipment onboard six Crosbie Offshore Supply Vessels as of May 1981.

103C Radio Equipment onboard six Crosbie Offshore Supply Vessels as of May 1981.

104A General Arrangement Offshore Standby Rescue Vessel Drawing Number: 8219P-01 – Scale: 1:100, October 1982.

104B Transparency: General Arrangement Offshore Standby Rescue Vessel; Drawing Number: 8219P-01 – Scale: 1:100, October 1982.

104C Specifications of Offshore Standby Vessel, 2 pages, signed by C. A. Nicol, Vice-President, SEAGEM Inc.

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2) Volume 5 Physical and Environmental Considerations Mobil et al: Hibernia J-34;
3) Approval for Drilling: Hibernia J-34 by Newfoundland and Labrador Petroleum Directorate, November 13, 1981.

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2) Drilling Program Approval issued by Energy, Mines & Resources, October 29, 1981;
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2) Mobil Oil Canada Limited Grand Banks Contingency Plan, April 1980, Unit 2, Supporting Environmental Information Manual.

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114 NORDCO Limited Forecast Verification Graphs for February 14-15, 1982.

115 Telex from NORDCO Limited to Mobil Oil Canada Limited September 1, 1982 re: Definition of Parameters in Site Specific Forecasts.

116 Graphs of Weather Forecasts, February 13-15, 1982, 10 pages, presented by Commissioner Pardy.

117 Marine Forecast and Weather Observations for February 14-15, 1982, presented by Stuart Porter, Weather Observer, Atmospheric Environment Centre.

118 1) Wave Record Information for Station 140, *Zapata Ugland* Identification No. 18-2-104;
2) Maximum Wave Height Statistics, Tape No. 103, February 11-15, 1982;
3) Characteristic Height in Metres for Station 140, *Zapata Ugland* and 156, *Ocean Ranger* for January – February, 1982.

119 Wave Data from the *Zapata Ugland*, Station 140, February 14-16, 1982.

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2) *Ocean Ranger* Stability Report for February 9, 1982;
3) *Ocean Ranger* A.M. Status Report to ODECO Drilling of Canada Limited, St. John's for February 14, 1982;
4) *Ocean Ranger* Stability Report dated February 9, 1982, Working Copy for February 14, 1982.

121 *Ocean Ranger* Ballast Tanks Configuration for February 14, 1982.

122 Various *Ocean Ranger* Reports, 89 pages

Pgs. 1-6, A.M. Reports January 28,29,30, 1982;
Pgs. 7-69, Two Hour Logs January 1-31, 1982;
Pgs. 70-89, A.M. Back-Up Reports July 12-21, 1981.

123 Physical Evidence Recovered from *Ocean Ranger* during July 1982 Dive Survey:

1) Brass Rod & Bolt;
2) Base;
3) Solenoid Valve and Dust Cover.

124 List of Condition of Solenoid Valves as retrieved from July, 1982 Dive Survey of the *Ocean Ranger*.

125 Hand Drawing of Lower Control Panel Solenoid Banks presented by Counsel for ODECO Drilling of Canada Limited.

126 Enhanced Exhibit 74B, Mimic Diagram of Control Face Port Hull and Starboard Hull presented by Commissioner Furst.

127 Selected American Bureau of Shipping Documents, 23 pages, reviewed by Mr. John L. Wilson, Principal Surveyor, American Bureau of Shipping.

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129 Photos (four), Exterior Views of Ballast Control Room, presented by Mr. Garland Elsworth, former Weather Observer, *Ocean Ranger*; identified by Mr. Frank Jennings, former Ballast Control Operator, *Ocean Ranger*.

130 Ocean Drilling and Exploration Company: Inter-office correspondence dated July 3, 1978; Subject: Height correction coefficients for wind speed readings.

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139 Extract from United States Coast Guard Regulations for Mobile Offshore Drilling Units 46 CFR 109.215; 109.217, December 4, 1978.

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To: Officer in Charge, Marine Inspection, United States Coast Guard, January 1, 1982.

141 Report by Toolpusher Kent Thompson to Ocean Drilling and Exploration Company on the resignation of Captain Karl Nehring.

142 Drilling Superintendent's Report on 5° Port Aft List Aboard *Ocean Ranger*, February 6, 1982.

143 Anchoring Report Hibernia J-34 November 29, 1981.

144 Motion Compensation Systems Diagram.

145A *Ocean Ranger* Morning Reports to ODECO Drilling of Canada Limited, St. John's, December, 1981.

145B *Ocean Ranger* Morning Reports to ODECO Drilling of Canada Limited, St. John's, January, 1982.

145C *Ocean Ranger* Morning Reports to ODECO Drilling of Canada Limited, St. John's, February, 1982.

146 Correspondence from W. M. Hannan, American Bureau of Shipping:

1) To G. N. Troxell of Ocean Drilling and Exploration Company, February 18, 1976,
2) To Republica de Panama, February 18, 1976.

147 *Ocean Ranger* Model Tests conducted by Offshore Technology Corporation 1974, extract from Exhibit #57, pages 1, 12, 23.

148 Summary Table 6 of Stability Reports for the *Ocean Ranger*, October 12, 1981 and October 18, 1981.

149 Report to Jim Wilkinson, Vice President of Ocean Drilling and Exploration Company from Jim Counts, Drilling Superintendent, *Ocean Ranger*, in reference to the resignation of Captain Karl Nehring. Presented by Counsel for ODECO.

150 Correspondence from Mr. Merv Graham, Drilling Superintendent, Mobil Oil Canada Limited to Mr. Gordon Gosse, Newfoundland and Labrador Petroleum Directorate, February 10, 1982; correspondence from Mr. Graham to ODECO Drilling of Canada Limited, February 12, 1982 re: February 6 List.

151 Summary of Phone Calls, Notes and Memory, preceding, during and after the *Ocean Ranger* Event on February 15, 1982, by Merv Graham, Drilling Superintendent, Mobil Oil Canada Limited.

152 Correspondence from Messrs. Stirling, Ryan, Reid, Harrington, Andrews and Lilly, June 25, 1982 to L. A. Martin, Commission Counsel re: Hibernia J-34 Well Suspension Program.

153 *Ocean Ranger* Drill String as Recorded by the *Neddrill 2*, June 10, 1982, extract from Exhibit 196, Canada Oil and Gas Lands Administration's Report.

154A Transcript, Magnetic Log Recorded at Search and Rescue Emergency Centre, St. John's February 15, 1982, Page 1-200.

154B Transcript, Magnetic Log Recorded at Search and Rescue Emergency Centre, St. John's February 5, 1982, Page 201-387.

155 Memory Jogger Notes of February 13-15, 1982 by Merv Graham, Drilling Superintendent, Mobil Oil Canada Limited.

156 Charter Party between Mobil Oil Canada Limited and Seabase Nova Scotia Limited, January 15, 1982, for Services of Supply Vessel *MV Seaforth Highlander.*

157 *SEDCO 706* Plan of Upper Deck.

158 *SEDCO 706* list of Radio Room Equipment and New Radio Equipment installed since February 14, 1982, issued October 14, 1982.

159 Typed Transcript of Exhibit #18, Radio Logs and Weather, *SEDCO 706* February 14, 15, 1982.

160 *SEDCO 706* Chart Layout of the Radio Console.

161 Extracts from *Zapata Ugland* Radio Logs for February, 1982.

162 *Seaforth Highlander* Logs for period February 14-23, 1982, including Official Log, Chief Officer's Log, and Diary of Radio Telephone Service.

162A Typed Transcript of *Seaforth Highlander* Logs for February 14-15, 1982.

163 General Arrangement for Anchor Handling Tug/Supply Vessel, *Seaforth Highlander.*

164 General Arrangement for T.S. Anchor and Rig Chain Handling Tug/Supply Vessel, *Seaforth Jarl.*

165 Letter of Commendation to the *MV Seaforth Highlander* Crew from Mobil Oil Canada Limited, March 30, 1982.

166 Extract from Harding Safety Enclosed Lifeboats Brochure.

167 Certificate of Vessel Delivery/Redelivery of *MV Seaforth Highlander* from Seaforth Maritime Limited to Mobil Oil Canada Limited, January 15, 1982.

167A Safety Inspection Certificate for *MV Seaforth Highlander* issued by Department of Transport, January 28, 1982.

167B Record of Safety Equipment for *MV Seaforth Highlander* issued by Department of Transport, June 27, 1980.

167C Ship Survey Record for *MV Seaforth Highlander* dated February 18, 1982.

168 Handwritten Standing Orders issued by R.S. Duncan, Master and signed by Crew of *MV Seaforth Highlander.*

169 Handwritten Standing Orders issued by R.S. Duncan, Master, for Bridge Watchkeeping personnel, *MV Seaforth Highlander.*

169A Typed Transcript of Exhibit 169, Handwritten Standing Orders.

170 Sketch: *MV Seaforth Highlander* Course 1200 Hours Local February 14, 1982 to 0105 Hours Local February 15, 1982, presented by R.S. Duncan, Master.

171 Sketch: *MV Seaforth Highlander* Position 0105 Hours Local February 15, 1982 presented by R.S. Duncan, Master.

172 Sketch: *MV Seaforth Highlander* Position 0150 Hours Local presented by R.S. Duncan, Master.

173 List of Publications maintained onboard *MV Seaforth Highlander.*

174 Merchant Shipping Notice No. M1019 current December 31, 1981 issued by Department of Trade, London.

175 Mobil Oil Canada Limited, St. John's, Communications System with Offshore Rigs, Supply Vessels, Helicopters; Frequencies Listed.

176 Notes presented by Mr. Keith Senkoe, Drilling Foreman, *SEDCO 706* for February 14, 1982.

177 Sketch: *MV Nordertor* Position 2000 Hours Local February 14, 1982 to 0130 Hours Local February 15, 1982, presented by Baxter Allingham, Master.

178 Sketch: *MV Nordertor* Position 0130 Hours Local February 15, 1982 to Arrival on *Ocean Ranger* Location 0340 Hours Local February 15, 1982, presented by Baxter Allingham, Master.

179 Correspondence from R.A. Sutherland, United States Coast Guard to Ocean Drilling and Exploration Company, December 18, 1979, re: Inspection for Certificaton of Mobile Offshore Drilling Unit (MODU) *Ocean Ranger*.

180 Typed Transcript of Exhibit 180A, Distress Log from R. Fraser, Drilling Foreman, *SEDCO 706*, February 15, 1982.

180A Distress Log from R. Fraser, Drilling Foreman, *SEDCO 706*; (Handwritten Notes), February 15, 1982.

181 Well Locations and Positioning of *MV Boltentor* February 15, 1982 presented by James Davison, Master.

182 Rig Anchor Buoy and Positioning of *MV Boltentor* February 15, 1982 presented by James Davison, Master.

183 *Zapata Ugland* Daily Log for February 14, 1982.

184 *Zapata Ugland* Captain's Log for February 14-15, 1982.

185 *Zapata Ugland* Daily Log for February 16, 1982.

186 Canadian Coast Guard Telex of February 15, 1982 to Search and Rescue Emergency Centre re: All Ships Broadcast.

187 Interoffice Correspondence dated February 15-19, 1982 re: *Ocean Ranger* presented by K.F. Beattie, Logistics Supervisor, Mobil Oil Canada Limited.

188 Mobil Oil Canada Limited, Correspondence:

1) To All Boat Captains from K.F. Beattie, September 10, 1982 ;
2) To All Boat Captains from K.F. Beattie, February 15, 1983;
3) To Neil Blackburn from K.F. Beattie, April 20, 1983;
4) To All Boat Captains, Reporting of Positioning of Standby Vessels Rules from K.F. Beattie, August 31, 1982;
5) To Mobil Radio Operators re Supply Boat Movements from S. Romansky, August 20, 1982.

189 Search & Rescue Mission Report on *Ocean Ranger*, February 15. 1982.

190 Search & Rescue Emergency Centre, St. John's, Watchkeeper's Notes, February 15 – March 1, 1982.

191 Extract from "Nato Operations Flight Manual", of April 1, 1980.

192 103 Rescue Unit Helicopters Average Serviceability Rate by Month.

193 Correspondence from 103 Rescue Unit dated July 27, 1982 from Major K.T. Gathercole to Mr. Norm Whalen.

194 103 Rescue Unit Annex A, Standing Operating Procedures, Attachments 1-7 of July 27, 1982, letter.

195 103 Rescue Unit Helicopter Usage January 1977 to May 1982.

196 Re-entry and Suspension of Hibernia J-34, July 15, 1982, from Canada Oil and Gas Lands Administration.

197 Royal Canadian Mounted Police Exhibit Report entitled Security Systems Section, re: *Ocean Ranger* Disaster dated July 14, 1982.

198 Index of Autopsy Reports of Victims of *Ocean Ranger* Disaster submitted by Dr. Eric Pike, Forensic Pathologist, General Hospital, Health Sciences Centre.

199 Document submitted by Dr. Eric Pike regarding Changes in Human Body with Falling Body Temperatures.

200 List of Crew Members Recovered by Date, Time and Location compiled from Royal Canadian Mounted Police information.

201 Rescue Co-ordination Centre (RCC) Halifax, Watchkeeper's Log for February 15-25, 1982.

202 Search and Rescue Special Report (SAR) *Ocean Ranger* February 15, 1982.

203 Addendum to Search and Rescue Special Report.

204 Summary report of Investigation into circumstances attending the foundering of the Russian Vessel *Mekhanik Tarasov* in the North Atlantic on February 16, 1982, issued by Canadian Coast Guard, Marine Casualty Investigations, June 1982.

205 Map of East Coast of Canada with co-ordinates of 65°.45° Latitude and Longitude Boundaries identifying ship locations in response to distress messages.

206 Identification of Search Area on February 15, 1982, plotted on Canadian Hydrographic Chart #8012 by Search & Rescue.

207 Identification of Search Area on February 16, 1982, plotted on Canadian Hydrographic Chart #8012 by Search & Rescue.

208 Identification of Search Area on February 17, 1982, plotted on Canadian Hydrographic Chart #8012 by Search & Rescue.

209 Identification of Search Area on February 18-19, 1982, plotted on Canadian Hydrographic Chart #8012 by Search & Rescue.

210 Identification of Search Area on February 20-21, 1982, plotted on Canadian Hydrographic Chart #8012 by Search & Rescue.

211 Identification of Items Recovered, Date and Area plotted on Canadian Hydrographic Chart #8012 by Search & Rescue.

212 Eight Photographs of *Mekhanik Tarasov* Rescue Mission presented by B. Leonard, Canadian Coast Guard Rescue Officer.

213 "Search and Rescue Order and Procedures", on authority of the Chief of Defence Staff, National Defence, February, 1976 (One copy held by Registrar).

214 Correspondence from the Director of Interdepartmental Committee on Search & Rescue (ICSAR) dated March 8, 1983 to Members re: Major Marine Disaster Plan.

215 Audio and Video Tape Index representing 32 hours of actual tape taken during the *Ocean Ranger* Dive Survey conducted by Hydrospace Marine Services July 14 – August 1, 1982.

216 Listing of Lower Hull Tank Soundings taken during the Dive Survey July 14 – August 1, 1982.

217 Hydrospace Marine Services Dive Log maintained by Max Ruelokke, Vice President and General Manager, July 14 – August 1, 1982.

218 Hydrospace Marine Services Divers' Log July 14 – August 1, 1982.

219 Copy of Side Scan Sonar Survey of March 8, 1982, Figure 4, prepared for Mobil Oil Canada Limited by McElhanney Surveying and Engineering.

220 "Engineering Reports A to G", prepared by Aviation Safety Engineering Facility, Aviation Safety Bureau, Transport Canada. Completed September 8, 1983:

Report A – EP 266/82 – Portholes Examination
Report B – EP 90/83 – Porthole Glass Pressure Tests
Report C – EP 265/82 – Analysis of Solenoid Control Valves
Report D – EP 331/83 – Ballast Control Mimic Panel Analysis
Report E – EP 332/83 – Ballast Control Panel Light Bulb Analysis
Report F – EP 333/83 – Ballast Control Panel Tests
Report G – EP 195/82 – Ballast Control Electrical System & Overall Analysis

221 "Analysis of Lifesaving Equipment Performance", submitted by R.L. Markle, Acting Chief, Survival Systems Branch, Merchant Vessel Inspections Division, United States Coast Guard, November 29, 1982.

222 Billy Pugh Personal Flotation Device, sample of Lot 1A recovered from search area.

223 Japanese Industrial Standard, Tempered Glasses for Ships' Side Scuttles, F2410 – 1955 obtained from American Bureau of Shipping.

224 Technitrol Canada Limited Report on Lifesaving Equipment, September 9, 1983.

225 Portion of Recovered *Ocean Ranger* Liferaft #715 Showing Blisters.

226 Portion of Recovered *Ocean Ranger* Liferaft #715 Seam Width.

227 Portion of Recovered *Ocean Ranger* Liferaft #715 Seam Width.

228 Portion of Recovered *Ocean Ranger* Liferaft #715 Seam Width.

229 15mm wide rescue lines from recovered liferaft.

230 Sample inflatable raft material showing seam width.

231 Seat belt from recovered Harding lifeboat.

232 Portion of recovered Harding lifeboat hull.

233 Portion of recovered Watercraft hull.

234 Portion of woven fibreglass from recovered Harding lifeboat.

235 Portion of chop fibreglass from recovered Watercraft lifeboat.

236 Video Tape Index for Ballast Control Panel Testing conducted by Aviation Safety Engineering and the Royal Commission and Index of Slides received from Aviation Safety Engineering.

237A Government of Newfoundland & Labrador Petroleum Directorate's "Technical Investigation of *Ocean Ranger* Accident", Volume 1, April, 1983.

237B Government of Newfoundland & Labrador Petroleum Directorate's "Technical Investigation of *Ocean Ranger* Accident", Volume 2, Appendices, April, 1983.

238 Report of The Robert Gordon Institute of Technology Offshore Survival Centre, Aberdeen, Scotland.

239 Report on "Offshore Installation Support by Standby/Rescue Ships", submitted by Hamish McDonald, Manager, Maritime Rescue Section of The Robert Gordon Institute of Technology.

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241 *MV Seaforth Highlander* Engine Room Log for February 14-15, 1982.

242 Memory Jogger Notes presented by Peter Kapral, Drilling Foreman, Mobil Oil Canada Limited for February 13-14, 1982.

243 Additional Notes from Peter Kapral noted as Kapral #2.

244 Resume of Brinley Davies, Chief, Communications & Computer Engineering Division, Canadian Coast Guard, Transport Canada.

245 Map depicting Areas of Radio Coverage, VHF and MF, East Coast of Canada submitted by Brinley Davies.

246 Hand Drawn Document of Transmitter and Receiver Antenna Coupler submitted by Brinley Davies.

247 Comparative Communications Range of 2182 KHZ Ground Wave Signal as a Function of Transmitter Output Power submitted by Brinley Davies.

248 Map depicting the location of *Zapata Ugland, SEDCO 706* and *Ocean Ranger* in relation to the Avalon Peninsula.

249 Map depicting INMARSAT 800 MHZ Coverage Capability.

250 Report entitled "The Stand-by Boat Service on the Continental Shelf", prepared for the Norwegian Petroleum Directorate, December 1982.

251 Certificates of Training (2), Joseph Wayne Berthier, Former Safety Engineer, *Ocean Ranger*.

252 Extract from Ocean Drilling & Exploration Company's Industrial Relations Safety Manual.

253 Detail Air Inlet, revised work plan submitted to Canada Oil and Gas Lands Administration by Nan Halfweeg of Wijsmuller Salvage B.V.

254 Flotation Cylinder, revised work plan submitted to Canada Oil and Gas Lands Administration by Nan Halfweeg of Wijsmuller Salvage B.V.

255 Diary of Events for February 15-24, 1982 by John Greer, Director, Emergency Measures, Province of Newfoundland & Labrador.

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283.1 Replacement for Section 5 and Appendix 5 of Report No. 3, Final Calculations on the Ballast Pumping System Capability of the *Ocean Ranger*.

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287 Report #2 – "Calibration Results", dated September 1983.

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STATISTICS TO MARCH 22, 1984

• No. of days of Hearings:	89
• No. of witnesses heard:	102
• Pages of transcript:	14,281
• No. of exhibits entered:	321

Item A-10

Royal Commission on the *Ocean Ranger* Marine Disaster
Canada

Commission Royale sur le Désastre Marin de l'*Ocean Ranger*
Newfoundland · Terre-Neuve

NOTICE

Part One of the Commission's mandate establishes the Terms of Reference for the inquiry into the loss of the Ocean Ranger. The technical evidence arising from this investigation will be heard during the final phase of the public hearings that will resume in the fall.

Part Two instructs the Commission to inquire into "both the marine and drilling aspects of practices and procedures in respect of offshore drilling operations" off Eastern Canada. This inquiry, which is proceeding in parallel with the Part One investigation, will draw on three main sources of information: evidence given regarding the loss of the Ocean Ranger; the results of studies that are being undertaken for the Commission; and briefs or submissions presented to the Commission.

The Commission has set as its goal: to identify practical means of improving the safety of Eastern Canada offshore drilling operations. The studies directed towards this goal are being approached under four principal areas;

- Environment — evaluation of design and operations criteria dictated by the physical environment offshore;
- Design — the conception, design, construction, classification, certification and equipping of drilling units used in offshore operations;
- Safety — the elements of offshore drilling operations related to human safety including all aspects of safety of life at sea including rescue, occupational health and the certification and training of the marine and drilling crews;
- Regulation — the manner in which offshore drilling operations are controlled by rules, regulations and guidelines and their adequacy in relationship to safety.

The Commission invites knowledgeable people and organizations to make submissions addressed to this goal. Anyone wishing to make such a contribution to the Commission's work should do so in writing by December 31, 1983. Submissions should be sent to:

David M. Grenville
Commission Secretary
Royal Commission on the Ocean Ranger Marine Disaster
P. O. Box 2400
St. John's, Newfoundland
A1C 6G3

from whom further information about the form and scope of submissions can also be obtained.

Public hearings related to Part Two of the Commission's Terms of Reference will be held at a place and time to be announced.

Item A-11
Royal Commission Staff

COMMISSION SECRETARY:	David M. Grenville, M.A., M.B.A.
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Secretaries to Commissioners	Diane M. Rayner Agnes M. Collins
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Associate Counsel	David B. Orsborn, B.Comm., C.A., LL.B
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APPENDIX B

INDUSTRY BACKGROUND

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Item B-1

A Brief History of Offshore Drilling

The petroleum industry as we know it today is often depicted as a monolithic giant affecting every aspect of the global economic system. Though the petroleum industry has expanded its operating base to include both industrial and consumer product manufacturing and distribution, the primary source of its raw materials comes from the exploration and production of oil and gas reserves, both on land and offshore. The petroleum industry began in the nineteenth century with the discovery of substantial hydrocarbon deposits, primarily in North America. The increased economic need for petroleum, coupled with easily accessible reserves, provided the industry's pioneers with the stimuli they required to locate and exploit petroleum resources and to develop increasingly efficient drilling technology. Around 1900, these same motives induced expansion into exploratory drilling over water, and by the early 1950s offshore exploration and production had become an industry in its own right, with its own experts, service companies, and equipment to cope with the unique problems of drilling over water. The development of today's sophisticated offshore technology was a gradual process, evolving over the last 80 years.

The first recorded offshore drilling venture took place in the late 19th century near Santa Barbara, California, where the presence of oil had long been recognized. In the 1860s, natural asphalt seepages were extracted from the beaches and prospectors eventually discovered that oil bearing formations extended underneath the ocean. In 1897 the first "over water" exploration wells were drilled from wooden stages which extended from the shoreline, and by 1900, beaches in the Summerland, California area displayed clusters of wharves up to 1200 feet in length, from which exploration wells were successfully drilled.

Oil and gas seepages, similar to those found on the California coastline, were prevalent in the Caddo Lake area of northeastern Texas and northwestern Louisiana, where in 1870 a well aimed at locating water encountered natural gas. This accidental discovery caused numerous technical problems associated with well control. Blowouts were frequent in early gas wells and in some instances uncontrolled wells burned for years. As a result of the Caddo Lake experience, government enacted well-control regulations and, through lease sales, limited the development of land surrounding and beneath the lake. To conduct drilling operations over water, equipment was transported by barge to the drill site where a drilling platform and pipe rack, like those used on land sites, were constructed. Wooden pilings were driven to provide a fixed base for the drilling equipment. In 1911, Gulf Oil Limited produced the first oil from an inland lake using this type of drilling system. Platform design and production techniques pioneered by Gulf in Caddo Lake became an acceptable standard in the industry and were used to produce oil in Lake Maracaibo, Venezuela in the early 1920s. Derrick foundations progressed from wood to concrete, and by the 1930s steel became the standard.

Geophysical and seismic exploration along the coastlines of Texas and Louisiana produced numerous prospects, but the open bays, lakes, swamps and marshes of the area presented unique problems and required a totally different approach. Because of the silty subsoil of the Gulf Coast, Texaco Inc. commissioned the construction of a submersible barge equipped with a derrick and drilling equipment for exploration on inland waterways and lakes. The barge could be floated to a drilling site, flooded and submerged to rest on the shallow bottom which provided a solid support for drilling. This innovative concept eliminated the costs of constructing fixed platforms because the barge could be refloated and moved to another site when drilling was completed. The first submersible barge, consisted of two barge hulls each with several watertight compartments, was designed to operate in ten feet of water. A distribution manifold with seacocks adjusted the flow of water during submerging. A steel superstructure supported the derrick, drilling machinery, pipe racks, and ancilliary equipment such as mud tanks and pumps. Submersible barges provided an efficient and economical method for exploration of inland waterways.

As exploration in the Gulf of Mexico expanded in the 1930s, offshore exploration was still restricted to drilling from fixed platforms. In 1947 Kerr McGee Oil Industries pioneered an innovative platform design, which was considerably smaller than those previously used in the Gulf of Mexico. The derrick and basic drilling machinery were located on a small fixed platform, with ancilliary equipment, consumables and crew's quarters located on a floating tender. Since the platform and tender were located 10.5 miles offshore, they had to withstand local wind and wave forces. This design proved quite effective but the mooring system was not always capable of keeping the tender on location during poor weather conditions.

The oil industry responded favourably to Kerr McGee's innovative concept, which subsequently inspired the design of floating structures for the entire drilling operation. In 1948, John Hayward designed a drilling platform combining the submersible barge and pile support concept. The barge hull could be floated to location, then submerged to rest on the bottom, providing the platform with the necessary support, freeboard and stability. Hayward's design incorporated two pontoons which could be ballasted or deballasted independently. By 1949, the industry's first mobile drilling platform was launched and operated on several locations in 18 foot water depths. In 1954 the Ocean Drilling and Exploration Company (ODECO) built a floating barge based on Hayward's concept, to operate in water depths up to 40 feet. Operators began to commission similar designs for deeper water depths, adding buoyant vertical columns at each corner of the platform in order to achieve better performance.

As activity in the Gulf of Mexico increased, other areas of the United States, principally the California coast, became interested in exploratory drilling. Here public pressures discouraged the use of fixed platforms and the industry was forced to examine alternate designs. The result was an experimental program in 1953, involving a converted navy vessel used to develop a ship-based floating drilling system. A cantilevered drilling platform was extended from the vessel amidship, and the experiment allowed designers to identify equipment and system improvements, particularly in counteracting the vertical motion of the ship (heave) and its effect on the drilling operation.

In 1956, the first purpose-built drill ship was completed. The drilling platform and derrick were located amidship over an opening in the hull called the "moonpool". The motion characteristics of the drill ship were improved substantially as more were designed, and improvements to the industrial and marine systems evolved rapidly. A slip joint to compensate for heave was developed, improved mooring systems were designed, and a subsea system was designed to position the wellhead on the ocean floor. The design of the slipjoint and heave compensation systems permitted drilling to continue in moderate seas and allowed the operator to suspend operations during storms.

The industry continued to design and improve drilling units that were stable, mobile and cost effective. Their research led to the evolution of truly mobile (self-propelled) floating drilling units, and through the 1960s the drilling fleet expanded in size and type. Four generic forms of mobile drilling units evolved from the design innovations tested in the 1940s and 1950s. Two of these were bottom supported; submersibles and self-elevating platforms. The other two were freefloating; drill ships and semisubmersibles.

Submersibles generally have an upper hull for drilling equipment and crew's quarters, and a lower hull for flotation while in transit and bottom support while in the drilling mode. The rig is usually towed to the drill site where its lower hulls are flooded until they rest on the sea floor. In this position, the submersible is a relatively stable drilling platform. Once the drilling is completed, ballast water is pumped out of the lower hulls and the submersible is refloated. Because the submersible is designed as a bottom supported drilling unit, its operation is limited to water depths of up to 150 feet. Given the increasing requirement for exploration in deeper waters, the submersible fleet has seen limited growth since the 1960s.

The self-elevating or "jack-up" rig is the most widely used platform employed by today's offshore drilling industry. The basic design first appeared in the 1950s. The jack-up has a large hull fitted with a number of retractable legs. The platform can be towed or self-propelled to a drill site with its legs drawn up above the deck. Once on location, the legs are lowered until they make contact with the seabed. The deck, supported by the legs resting on the sea floor, is then jacked up above the water until a sufficient air gap is created to permit drilling operations unhindered by wave action.

While jack-ups provide a stable drilling platform while on location, they are extremely unstable during towing and jacking operations and can only be used where the seabed provides a solid foundation for the legs. As with the submersible, jack-up rigs are restricted by water depth. Current designs can accommodate depths in the order of 350 feet.

The drill ship received more recognition after successful experimental programs in California in the late 1950s. The ship-shaped design permits a large deckload requiring less frequent resupply. The benefits of self-propulsion and superior seaworthiness allow drill ships to operate in deep water, with the assistance of either conventional mooring or dynamic positioning systems. However, because of the hull shape and its large surface area, drill ships tend to have poor motion response, particularly to heave. Since the efficiency of an offshore drilling program is contingent upon platform stability, the drill ship tends to be restricted to use in regions having small wave heights and low wind velocities. In Canadian waters drill ships are used on a seasonal basis in the Beaufort and Labrador Seas.

The semisubmersible evolved from the submersible drilling unit and was introduced in the early 1960s. It had been found that the submersible exhibited satisfactory stability characteristics during all stages of ballasting operations and, with certain structural changes, a submersible drilling unit could be designed to be partially submerged, providing a floating platform with good stability. As the industry began to explore deeper waters and harsher physical environments, the use of semisubmersibles became increasingly necessary. The structural arrangement of the semisubmersible consists of a deck, supported by a number of vertical columns, cross braces and pontoons which have sufficient buoyancy to float the entire structure. This arrangement makes the semisubmersible very stable and reduces the effects of wave action since much of the vessel is below the surface of the sea while drilling. The pontoons of the semisubmersible are designed for storing bulk liquids, such as fuel oil, drill water and salt water for ballast. When the semisubmersible moves into the drilling mode it is ballasted down by taking sea water into its ballast tanks. When drilling, the deckload changes continuously as supplies are consumed, and the rig takes on or pumps out ballast water to maintain its draft, trim and stability.

Since its introduction in the early 1960s, a wide variety of semisubmersible designs have evolved. Many of the early units were designed to operate in both the free floating and bottom supported condition (i.e. semisubmersible or submersible), and the drill floor and derrick were located at either the edge of, or overhanging, the deck structure. The *SEDCO 135* or "arrowhead" design is typical of the first generation of semisubmersibles.

In the 1970s, semisubmersible designs began incorporating improvements resulting from earlier experience in the Gulf of Mexico and the North Sea. The deck was made rectangular to increase deckload, and the drill floor was placed close to the centre of buoyancy, thereby reducing motion effects. Improvements were also made in the mooring systems and several rigs were fitted with either partially or totally dynamic positioning systems.

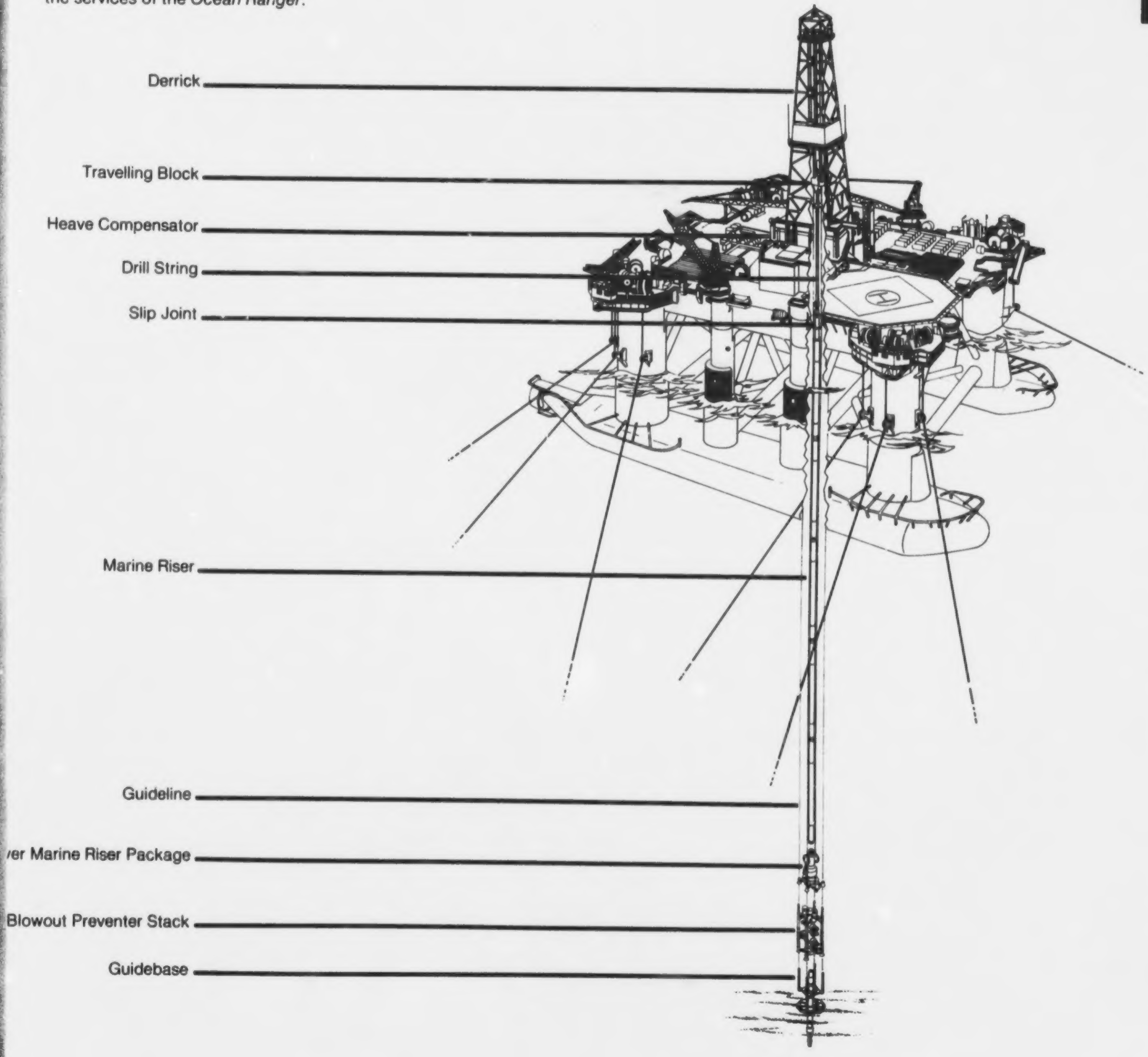
The semisubmersibles of the 1980s have more standardized structural designs which reduce construction costs; however, the basic principles of stability, mobility and reduced motion characteristics, upon which the first generation of semisubmersibles was designed, still apply.

The evolution of mobile offshore drilling units allowed exploration off the east coast of Canada with the use of drill ships, jack-ups and, particularly, semisubmersibles. Oil and gas exploration on Canada's Continental Shelf began in 1960 when geophysical and seismic surveys were undertaken to locate potential hydrocarbon reserves. The first exploratory well was the Pan Am Tors Cove which was drilled on the Grand Banks in 1966.

The pace of exploration continued as major oil companies (operators) including AMOCO, British Petroleum, Texaco, Esso and Mobil conducted exploratory drilling on the Grand Banks, on the Scotian Shelf and in the Labrador Sea. In 1979, a consortium made up of Gulf Canada Ltd., Mobil Oil Canada Ltd., Chevron Canada Ltd. and Columbia Oil and Gas, which had been granted exploration permits by the Federal Government of Canada and the Provincial Government of Newfoundland and Labrador, announced a major oil discovery. The discovery of the Hibernia field, which is estimated to contain 1.8 billion barrels of oil, was the largest discovery in Canada.

To determine the exact size of Hibernia's reservoir, the consortium developed an extensive exploratory drilling program. Since Mobil Oil Canada Ltd. (Mobil), a subsidiary of Mobil Corporation, had considerable offshore drilling experience in the North Sea, its partners designated it as the operator for the consortium. To undertake its exploratory drilling program, Mobil set up an office and shore base facilities in St. John's, Newfoundland, the major centre closest to the Grand Banks.

As operator, Mobil required a number of semisubmersible drilling units and therefore engaged the services of several major drilling contractors. In February, 1980, Mobil negotiated a contract with Ocean Drilling and Exploration Company Ltd. (ODECO) for the services of the *Ocean Ranger*.


Derrick
Travelling Block
Heave Compensator
Drill String
Slip Joint
Marine Riser
Guideline
er Marine Riser Package
Blowout Preventer Stack
Guidebase

Item B-2

The Industrial System for Offshore Drilling

The basic equipment used in drilling wells and the layout of the industrial system are essentially the same for offshore as for onshore drilling operations. A rotary rig has four major systems; they are the power, hoisting, rotating and circulating systems.

POWER SYSTEM

Most power systems on drill rigs are diesel-electric. A series of diesel engines coupled to generators produces the electric power for the rig's drive motors.

HOISTING SYSTEM

A rig's hoisting system supports the drill string and lowers it into or pulls it out of the well. It is also used to lower casing into the well and to lower into place or bring up wellhead and other equipment. The hoisting system is comprised of the drawworks, the derrick, the crown block, the travelling block and wirerope.

The *drawworks* consists of a large revolving drum around which wirerope is spooled. It contains a main drive and a braking system which allow the drum to turn at variable speeds in either direction and control the heavy loads attached to the hoisting system.

The *wirerope*, spooled on the drawworks, runs to the top of the *derrick*, over a large multiple pulley system called the *crown block*. It then runs back down the derrick, through another multiple pulley called the *travelling block*, back up over the crown block, down again to the travelling block and so on, depending upon the number of lines which have to be threaded. The drill string (drill pipe, drill collars and drilling bit) or any equipment which is to be raised or lowered, is suspended from the travelling block.

ROTATING SYSTEM

The rotating system is designed to rotate the drill bit in the well. It consists of the swivel, the kelly and kelly bushing, the rotary table and the drill string.

The *swivel*, fastened to a hook on the bottom of the travelling block is designed to support the weight of the *drill string*. While allowing the drill string to rotate, the swivel also provides a passageway for drilling mud pumped into and down the drill string.

Suspended immediately below the swivel is a square or hexagonal piece of pipe called the *kelly*. The kelly fits into a corresponding square or hexagonal opening in the *kelly bushing*, which in turn fits into the *rotary table*. The drill pipe is attached to the kelly and suspended from it.

The rotating motion required to turn the drill string and bit is transferred from the rotary table to the kelly bushing and then through the kelly to the drill string.

CIRCULATION SYSTEM

Drilling fluid, or *mud*, the principal component of the circulation system, is used to remove and bring to the surface the cuttings made by the drill bit at the bottom of the well, and to control underground pressures that are encountered as the drill penetrates certain geological formations. Mud is a mixture of fresh water, clay, chemicals and weighting material, transferred under pressure from the mud tanks to a flexible hose, called the *kelly hose*, which is connected to the swivel. The drilling fluid is pumped through the swivel down the kelly and the drill pipe, exiting at the bottom of the well through the drill bit. Since the drilling fluid is under pressure, it returns to the surface along the outside of the drill pipe, coating the inside of the well and sealing off the surrounding formations. The drill cuttings are removed at the surface, and the mud is then recycled down the well.

The density of the drilling fluid must be sufficient to counteract the pressures of gases or fluids contained in the formations which could cause a loss of well control and result in a *blowout*. If the density is insufficient to contain these pressures then control of the well can be maintained through the use of the *blowout preventers*. These are high pressure valves at the wellhead on the sea floor which, when activated by an operator on the rig, form a pressure-tight seal around the drill string at the top of the well, thus preventing the escape of gases or fluids.

DRILLING A WELL

Once the location of a well has been decided through seismic surveys and geological analysis, a rig is moved to the well site and drilling begins with "spudding in". A large diameter drill bit is affixed to the drill string and an initial section of the well is drilled. Additional sections of drill pipe (usually 30 feet in length) are added to the drill string until the well reaches a predetermined initial depth. Upon reaching this depth, the drill string and drill bit are pulled out of the hole and replaced by a string of large diameter pipe called *casing*. This casing is placed into the well in the same manner as the drill string; however, cement is pumped around the casing between it and the wall of the hole to hold it in place and to seal off the formations which have been drilled.

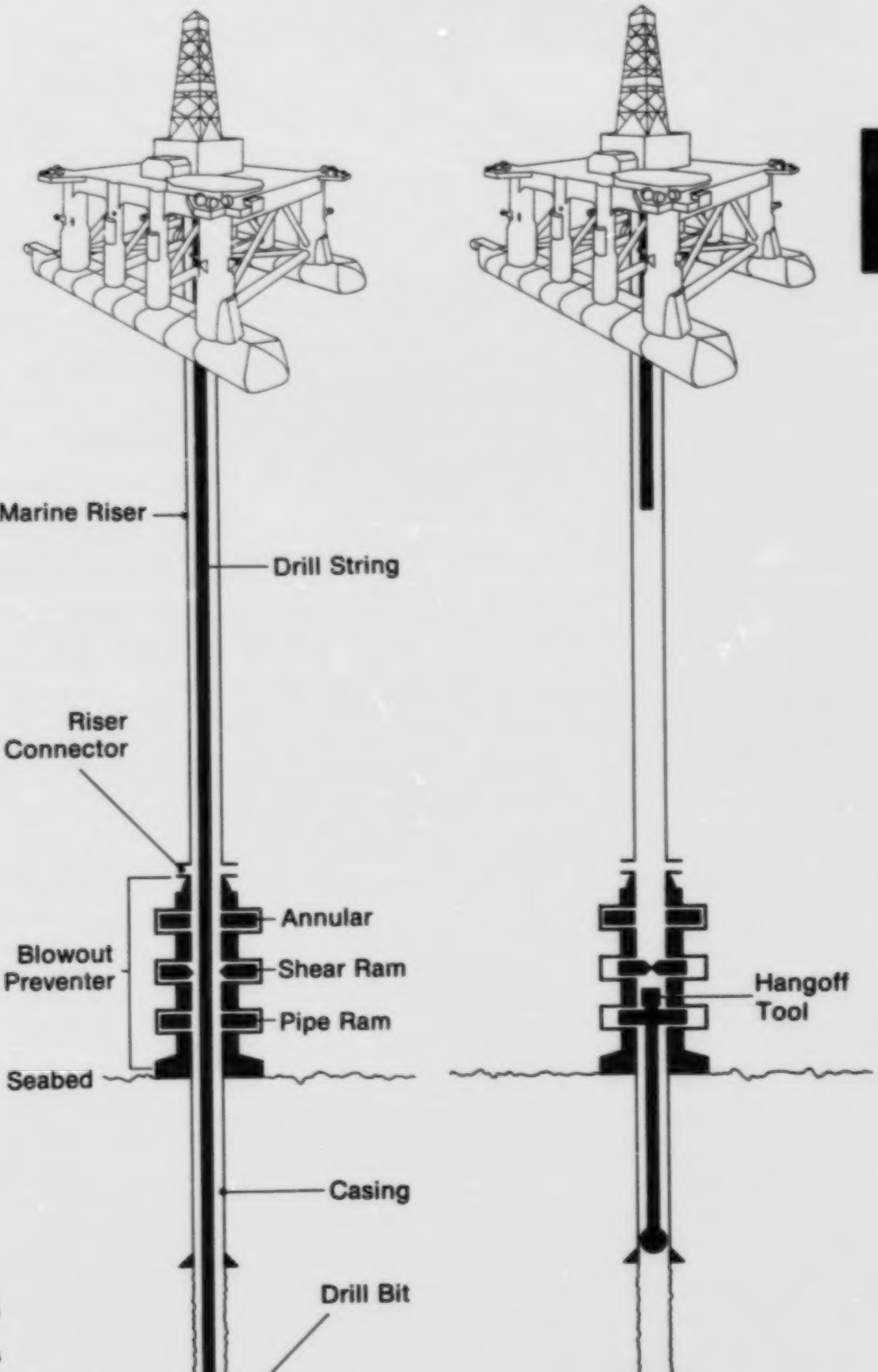
On offshore wells, a *guidebase* is usually placed on the seabed at the same time as the first string of casing is cemented in place. The guidebase is simply a template which is fastened to the first string of casing. A number of wire *guidelines*, running between the guidebase and the rig, are used to position equipment subsequently lowered into place.

After the first string of casing and the guidebase have been secured, a *marine riser* and *diverter system* are connected to the casing. The marine riser consists of large diameter pipe which is used to provide a return flowpath between the drill rig and the sea floor for drilling fluid. The diverter, a low-pressure blowout preventer, is placed on the top of the marine riser to divert the flow of formation fluids or gases away from the drill rig, in the event that control of the well is lost and a "kick" or blowout occurs.

Once the marine riser and diverter are installed, drilling resumes with a smaller drill bit. The new bit and drill string are lowered from the drill rig through the marine riser and the casing which is already cemented in place. The well is drilled to the depth at which the next string of casing, the *surface casing*, will be placed. The drill string, drill bit, marine riser and diverter are pulled up and placed on board the rig. The surface casing is then placed in the well, below the first casing, and cemented in place. The *blowout preventer stack* is then lowered to the sea floor attached to the marine riser, and secured to the top of the surface casing.

The subsequent operations consist of drilling further sections of open hole, removing the drill string and drill bit, and then installing and cementing strings of casing until the final depth of the well is reached.

Offshore drilling involves the same principles governing drilling on land. However, there are two major factors which distinguish floating drilling units from land drill rigs: the motions of the floating drilling unit and the physical separation of the drilling unit from the seabed. The evolution of float-


Marine Riser
Drill String
Riser Connector
Blowout Preventer
Annular
Shear Ram
Pipe Ram
Seabed
Casing
Drill Bit
Hangoff Tool

LEFT – NORMAL DRILLING

RIGHT – HUNG-OFF The drill string and bit have been pulled up and a hang off tool has been inserted in the string. The tool has been 'Landed' on a pipe ram in the BOP, stack, and the drill string above the tool has been unthreaded and raised into the riser. The drill string still in the well is now supported by the pipe ram. The shear ram is closed to further seal the well.

ing drilling systems has centred on developing methods to accommodate these differences.

MOTION COMPENSATION

One of the principal aims in the design of free-floating mobile offshore drilling units (MODUs) is the reduction of the unit's natural motion characteristics. The operating efficiency of conventional ship-shaped drilling units is reduced when sea conditions exceed 10-12 feet, whereas the semisubmersible unit operates effectively in rough sea conditions because its design places a large portion of the hull under water.

In addition to structural design features aimed at reducing motion effects, motion compensation systems have been developed to reduce further the effects of heave, pitch, roll, surge and sway. The efficiency of offshore drilling is adversely affected by any increase in these motions, until a point is reached where continued drilling operations become unsafe. Heave, usually the principal motion affecting operations, is accommodated by systems which include drill string compensators, marine riser tensioners, guideline tensioners and slip joints. Roll and pitch motions are accommodated by ball or flex joints located under the drill floor and/or on the lower marine riser package. Surge and sway motions are constrained by the unit's station-keeping (mooring) system.

MARINE RISER

The physical separation of the drilling unit from the seabed posed problems to the industry, particularly when offshore exploratory drilling moved into deeper water. To accommodate the required link between the drilling unit and the seabed, the marine riser was developed.

At the top of the riser a telescoping joint, called the slip joint, is fixed. The slip joint, which operates like a piston, is designed so that its inner barrel is connected to the rig just below the drill floor and its outer barrel is connected to the marine riser. The rig and the inner barrel of the slip joint move together vertically with the heave.

The slip joints used in offshore drilling are designed to cope with a total vertical movement of the rig of 60 feet. In such instances the rig's heave would be 30 feet – one half the total up and down movement. Therefore the rig can theoretically move up and down 30 feet without endangering the subsea equipment to which the marine riser is connected. Similarly, the ball joints at the top or bottom of the slip joint can accommodate lateral movements up to 10 degrees from the vertical. The 30 feet heave and 10 degree movement from the vertical represent theoretical design limits; operational limits are lower in order to provide a margin of safety. Should environmental conditions reach or exceed the established limits, the marine riser is usually *disconnected* from the subsea equipment to allow the unit to float freely without risking damage to the seabed installation.

HANGING-OFF AND DISCONNECTING

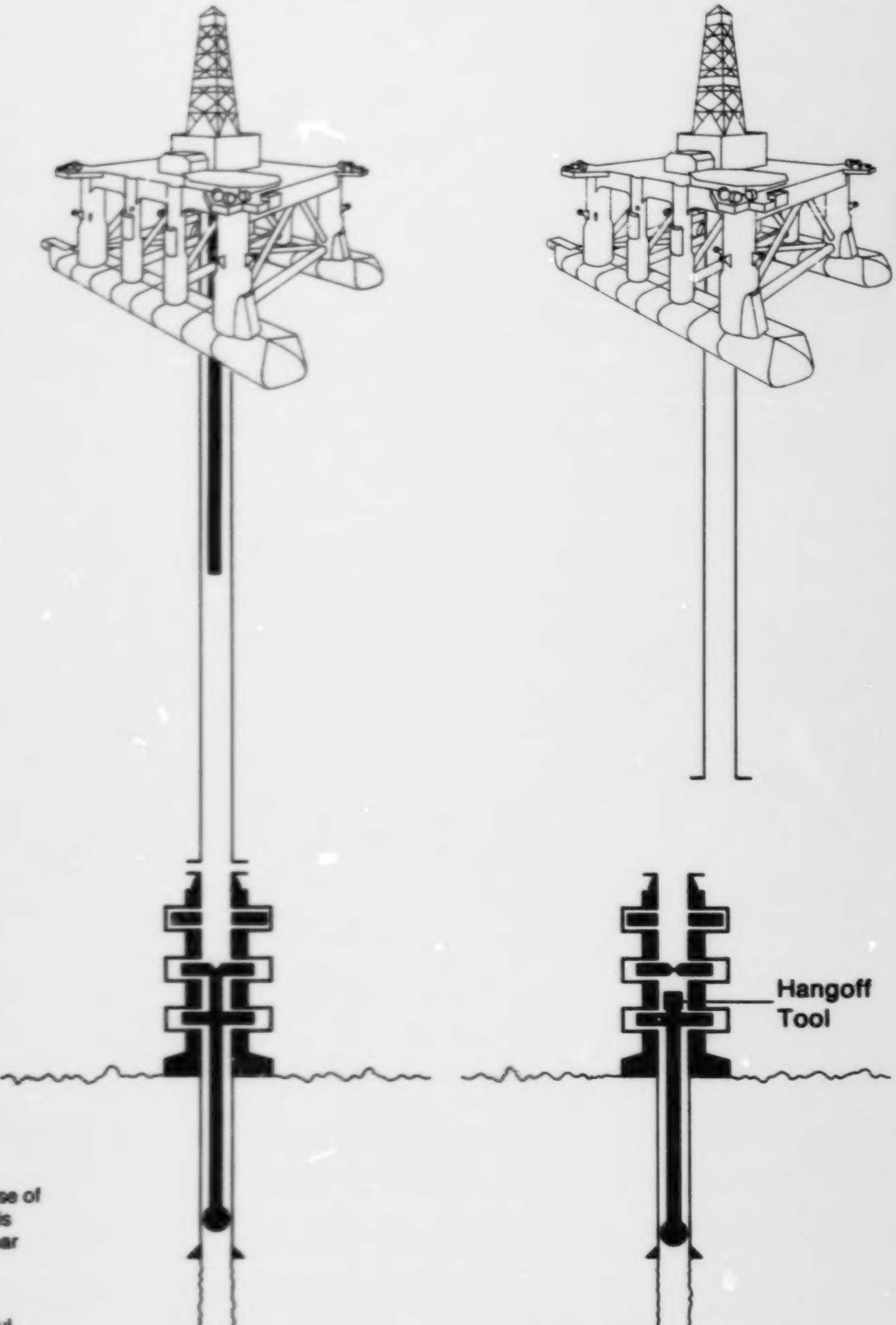
Prior to disconnecting the marine riser the drill pipe must either be pulled out of the well or *hung-off* in the blowout preventer stack. The hang-off procedure is carried out to secure the well and to prepare for the disconnect in such a manner that formation fluids cannot escape from the well and that the well can subsequently be re-entered as simply as possible.

Assuming that the operation at the time is drilling and that sufficient time is available, a typical hang-off sequence begins with a volume of heavy mud being pumped into the wellbore to counteract the loss of hydrostatic head which will occur when the riser is disconnected. Drill pipe is pulled out of the well until the bit is located inside the last string of casing. A further length of drill pipe is then pulled, which is at least equal to the distance from the rotary table to the ocean floor, and a *hang-off tool* is installed in the drill string at the surface. The drill string is run back into the well until the hang-off tool reaches the blowout preventer stack, and the bit is again near the bottom of the casing string.

The ram blowout preventers (pipe rams) are closed and the weight of the drill string is suspended on the pipe rams using the hang-off tool. The drill pipe is then unthreaded from the hang-off tool and pulled out of the blowout preventer stack. Finally, the blind (shear) rams are closed above the hang-off tool to seal the well. At this point the drill string has been hung-off and the marine riser can be disconnected from the blowout preventer stack, if necessary.

This procedure for hanging-off can take a significant amount of time depending upon several factors. In case of an emergency the process can be completed in a very short time by shearing the drill pipe. In this procedure the pipe rams are simply closed around a joint of drill pipe to support the weight of the drill string. The drill pipe above the pipe rams is then cut using the shear rams. The shear rams serve both to cut the drill pipe and to seal off the well. When this procedure has been completed the marine riser can be disconnected from the blowout preventer stack and the rig is free to move off the site, although re-entry into the well is more complex than when the pipe has been hung-off.

The procedure for disconnecting the marine riser is the same whether a hang-off tool has been used or the pipe has been sheared. The riser tensioners are adjusted to compensate for the entire weight of the marine riser and disconnection can then be effected through the hydraulic control of the connecting mechanism. Once it has been disconnected, the marine riser is pulled up using the riser tensioners until the slip joint is in its closed position. When required, the disconnect process can be completed in a matter of minutes.



LEFT – SHEARED OFF When the use of a hang-off tool is impossible, the string is supported by the pipe ram, and the shear ram is closed, severing the pipe.

RIGHT – HUNG-OFF AND DISCONNECTED After completing a successful hang-off or shear, the drill string can be pulled out of the riser, and the riser disconnected from the BOP stack. With the riser pulled up to avoid collision with the BOP, the rig is free to move off station.

CERTIFICATION

APPENDIX C

APPENDIX C

CERTIFICATION

1. BUILDER'S CERTIFICATE 215
   Issued at Tokyo, Japan by Mitsubishi Heavy Industries, Ltd.
   May 28, 1976.
2. CERTIFICATE OF REGISTRY 216
   Issued at New Orleans, Louisiana by the United States Coast Guard, August 5, 1980.
   Exhibit #4.
3. CERTIFICATE OF INSPECTION 218
   Completed and issued at Providence, Rhode Island by the United States Coast Guard December 27, 1979.
   Exhibit #5.
4. CERTIFICATES ISSUED FOR THE *OCEAN RANGER* 222
   American Bureau of Shipping and the United States Coast Guard.
   Extracts from Exhibits #5, 6, 7, 8, 9, and 83.
5. CORRESPONDENCE REGARDING MODU *OCEAN RANGER* INSPECTION FOR U.S. CERTIFICATION 222
   From R.A. Sutherland, United States Coast Guard to Ocean Drilling & Exploration Company December 18, 1979.
   Exhibit #179.
6. COGLA'S DIRECTIVE TO OFFSHORE OPERATORS REGARDING SURVIVAL SUITS 224
   July 7 and July 28, 1981.
   Extract from Exhibit #50.

Item C-1

MITSUBISHI HEAVY INDUSTRIES, LTD.
TOKYO, JAPAN

28th. May, 1976

Builder's Certificate

This is to certify that we, Mitsubishi Heavy Industries, Ltd., have completed the construction at Hiroshima, Japan, in May, 1976 of the drilling vessel named *Ocean Ranger* as described hereinafter, for and on behalf of Canan Offshore Limited, Hamilton, Bermuda, and K/S Fearnley Drilling & Exploration A/S N, Oslo, Norway.

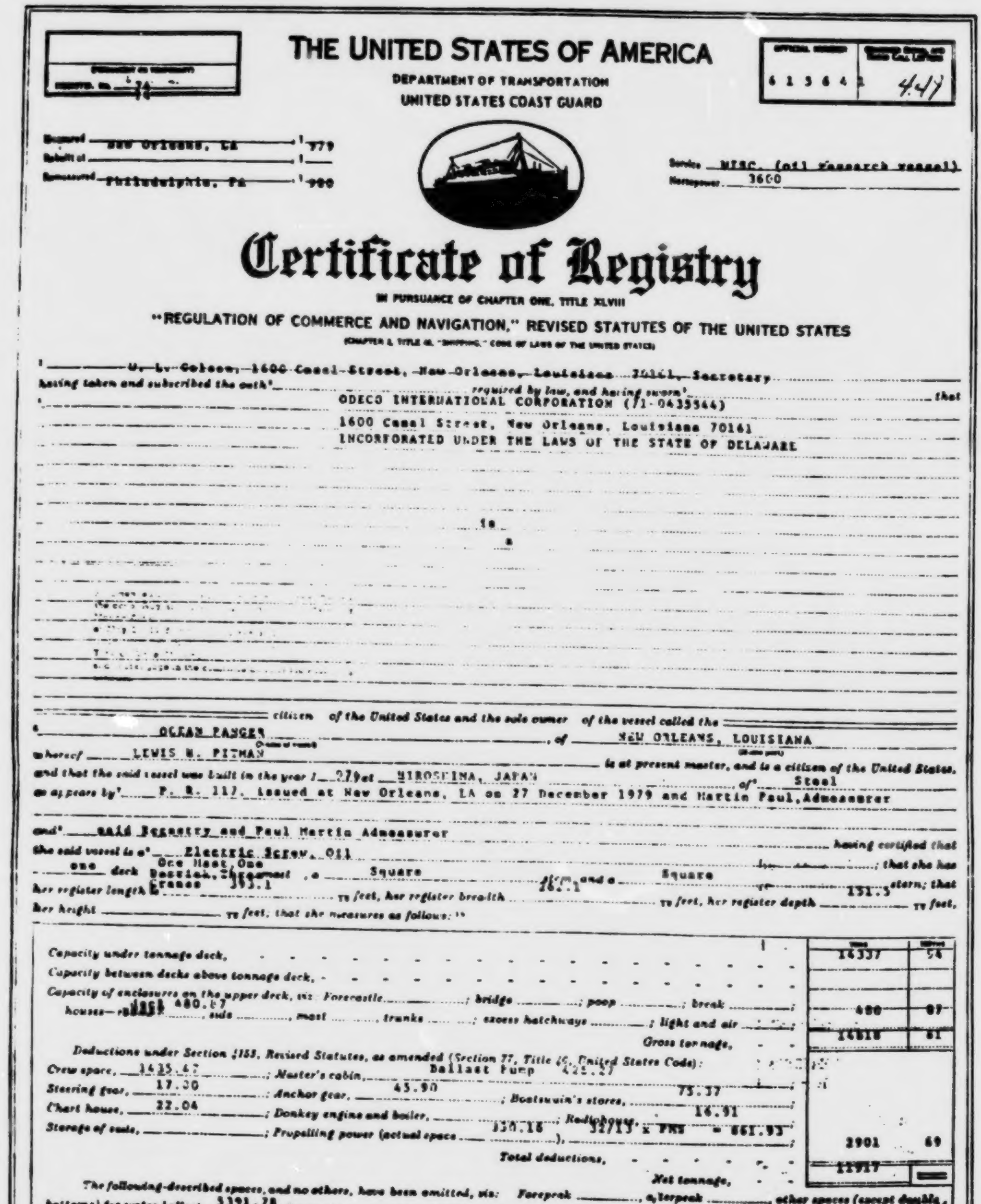
Official No.	7102-PEXT
Call Letters	3ENB
Name of Vessel	*Ocean Ranger*
Kind of Vessel	Semi-Submersible, Self-Propelled Drilling Vessel
Port of Registry	Panama, Republic of Panama
Length	393.11 feet
Breadth	262.13 feet
Height	151.50 feet
Designed Draft	80.00 feet
Gross Tonnage	14,913.66 tons
Net Tonnage	9,234 tons
Number of Decks	Two (2)
Principal Deck Machineries	One (1) set of Oil Drilling Machinery Eight (8) DC Generators Two (2) AC Generators (Diesel Engine Driven) One (1) Emergency Generator (Diesel Engine Driven) Three (3) Diesel Engine Driven Cranes Twelve (12) sets of Winch/Windlass (Electric Driven)

BUILDER:
Mitsubishi Heavy Industries, Ltd.

Yasuharu Yoshikechi
Attorney-in-fact

Item C-2

The information from the Certificate of Registry given on the facing page is taken from Exhibit #4, as entered in evidence October 25, 1982. The Certificate reproduced at right is identical to exhibit #4 except for minor discrepancies. Exhibit #4 was not suitable for reproduction.



6 1 3 6 4 | 447

THE UNITED STATES OF AMERICA

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

Measured ~~New Orleans, LA~~ 1979
Rebuilt at ___
Remeasured ~~Philadelphia, Pa~~ 1980

Service MISC. (oil research vessel)
Horsepower 3600

Certificate of Registry

IN PURSUANCE OF CHAPTER ONE, TITLE XLVIII

"REGULATION OF COMMERCE AND NAVIGATION," REVISED STATUTES OF THE UNITED STATES

~~U. L. Gibson, 1600 Canal Street, New Orleans, Louisiana 70161, Secretary~~

having taken and subscribed the oath ___ *required by law, and having sworn* ___ *that*

ODECO INTERNATIONAL CORPORATION (71-0435344)
1600 Canal Street, New Orleans, Louisiana 70161
INCORPORATED UNDER THE LAWS OF THE STATE OF DELAWARE

is a

___ *citizen of the United States and the sole owner of the vessel called the* OCEAN RANGER, *of* NEW ORLEANS, LOUISIANA

whereof LEWIS H. PITMAN *is at present master, and is a citizen of the United States, and that the said vessel was built in the year* 1979 *at* HIROSHIMA, JAPAN *of* Steel

as appears by P. R. 117, issued at New Orleans, LA on 27 December 1979 and Martin Paul, Admeasurer

and said Registry and Paul Martin Admeasurer *having certified that the said vessel is a* Electric Screw, Oil ___ *; that she has* one *deck* One Mast, One Derrick, Three Cranes *, a* Square *stern and a* Square *stern; that her register length is* 393.1 *feet, her register breadth* 262.1 *feet, her register depth* 151.5 *feet, her height* ___ *feet; that she measures as follows:*

	Tons	100ths
Capacity under tonnage deck,	14337	54
Capacity between decks above tonnage deck,		
Capacity of enclosures on the upper deck, viz: Forecastle ___; bridge ___; poop ___; break ___; houses— 480.87 *side ___, mast ___, trunks ___; excess hatchways ___; light and air ___;*	480	87
Gross tonnage,	14818	41
Deductions under Section 4153, Revised Statutes, as amended (Section 77, Title 46, United States Code): Crew space, 1435.47 *; Master's cabin,* Ballast Pump 425.27 *; Steering gear,* 17.30 *; Anchor gear,* 43.90 *; Boatswain's stores,* 75.37 *; Chart house,* 22.04 *; Donkey engine and boiler, ___; Radiohouse,* 16.91 *; Storage of sails, ___; Propelling power (actual space* 330.16 *),* 32/13 x PRS = 861.93	2901	69
Total deductions,		
Net tonnage,	11917	

The following-described spaces, and no others, have been omitted, viz: Forepeak ___, afterpeak ___, other spaces (except double bottoms) for water ballast 5391.78 *, open forecastle ___, open bridge ___, open poop ___, open shelter deck* 61.15 *, open houses* 1280.16 *, cabins ___, companions* 16.09 *, galley* 78.23 *, skylights ___, wheelhouse* 25.51 *, water closets ___; anchor gear* 2376.62 *, donkey engine and boiler ___, steering gear ___, light and air over propelling machinery ___, other machinery spaces* 35.36

And Louis H. Pitman, Agent *having agreed to the description and measurement above specified, the vessel has been duly* **REGISTERED** *at the* **PORT**;

GIVEN *under my hand and seal at the* **PORT** *of* NEW ORLEANS, LOUISIANA

this ___ *day of* ___

in the year One Thousand Nine Hundred and ___

IMPRESS SEAL OF U. S. COAST GUARD

Documentation Officer
By direction Officer in Charge, Marine Inspection

THE UNITED STATES OF AMERICA
DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

PERMANENT
(Permanent or Temporary)
REGISTER NO. 74

OFFICIAL NUMBER	COMMAND SIGNAL AND RADIO CALL LETTERS
615641	4 49

Measured New Orleans, LA, 1979
Rebuilt at ________, 1____
Remeasured Philadelphia, PA, 1980

Service MISC (oil research vessel)
Horsepower 3600

CERTIFICATE OF REGISTRY

IN PURSUANCE OF CHAPTER ONE, TITLE XLVIII
"REGULATION OF COMMERCE AND NAVIGATION," REVISED STATUTES OF THE UNITED STATES
(Chapter 2, Title 46, "Shipping," Code of Laws of the United States)

I[1] W.L. Colson, 1600 Canal Street, New Orleans, Louisiana 70161, Secretary
have taken and subscribed the oath[2] ________ required by law and having sworn[3] ________ that
[4] ODECO INTERNATIONAL CORPORATION (71-0435544)
1600 Canal Street, New Orleans, Louisiana 70161
INCORPORATED UNDER THE LAWS OF THE STATE OF DELAWARE

is
a

________ citizen of the United States and sole owner of the vessel called the
[5] OCEAN RANGER (Name of Vessel), of NEW ORLEANS, LOUISIANA (Home port)
whereof LEWIS H. PITMAN is at present master, and is a citizen of the United States,
and that the said vessel was built in the year 1976 at HIROSHIMA' JAPAN, of[6] Steel
as appears by[7] P. R. 117, issued at New Orleans, LA on 27 December 1979 and Martin Paul, Admeasurer
and[8] said Registry and Paul Martin Admeasurer having certified that
the said vessel is a[9] Electric Screw, Oil; that she has
one deck one mast, one derrick, three cranes mast, a Square stem, and a Square stern; that
her register length is 393.1 $\overline{10}$ feet, her register breadth 262.1 $\overline{10}$ feet, her register depth 151.5 $\overline{10}$ feet,
her height ________ $\overline{10}$ feet; that she measures as follows:[10]

	TONS	100THS
Capacity under tonnage deck,	14337	94
Capacity between decks above tonnage deck,		
Capacity of enclosures on the upper deck, viz: Forecastle ____; bridge ____; poop ____; break ____; houses – deck 480.87, side ____, mast ____, trunks ____; excess hatchways ____; light and air ____;	480	87
Gross tonnage,	14818	81
Deductions under Section 4153, Revised Statutes, as amended (Section 77, Title 46, United States Code): Crew Space, 1435.47; Master's cabin, Ballast Pump 426.27; Steering gear; 17.80; Anchor gear, 45.90; Boatswain's stores, 75.37; Chart house, 22.04; Donkey engine and boiler, ____; Radiohouse 16.91; Storage of sails, ____; Propelling power (actual space 350.16). 32/13 x PMS = 861.93; Total deductions,	2901	69
Net tonnage,	11917	—

The following-described spaces, and no others, have been omitted, viz: Forepeak ________, afterpeak ________, other spaces (except double bottoms) for water ballast 5391.78; open forecastle ________, open bridge, ________, open poop ________, oven shelter deck ________, open houses 35.96, cabins ________, companions 16.09, galley 78.23, skylights ________, wheelhouse 28.51, water closets 61.15; anchor gear 1280.16, donkey engine and boiler ________, steering gear ________, light and air over propelling machinery ________, other machinery spaces 1576.62

And[11] Lewis H. Pitman, Agent having agreed to the description and measurement above specified, the vessel has been duly REGISTERED at this PORT:

GIVEN under my hand and seal at the PORT of NEW ORLEANS, LOUISIANA.
this 5th day of August
in the year One Thousand Nine Hundred and 80

Impress Seal
of
U.S. Coast Guard

Original signed by W.A. GOUGIS
By direction Officer in Charge, Marine Inspection

---

[1] Insert name and address of person by whom oath or affirmation was made.

[2] Substitute "affirmation" when necessary.

[3] Substitute "affirmed" when necessary.

[4] Insert the name and business address of the owner. If there are two or more owners, give the name and business address of one of the owners (managing owner, if one has been designated) and the proportion owned by him, followed by the names of the other owners and the proportions owned by each. If any owner is a corporation, give the corporate name followed by the words "incorporated under the laws of the State of ________ (inserting the appropriate State name)."

[5] Insert the name exactly as it appeared on the preceding document, or, in the case of a first document, as it appeared on the application for official number. If the vessel has borne another name or a motorboat number prior to documentation or redocumentation give every such name or number in parenthesis, preceded by the prefis "as-," immediately

[7] On the first document of a new vessel, write in this blank "certificate of ________ builder". On every document other than the first, recite whether the last former document was permanent or temporary, the kind, number, date and place of issue of such former document, whether the original or a copy of the former document was surrendered, and the reason for issue of the new document.

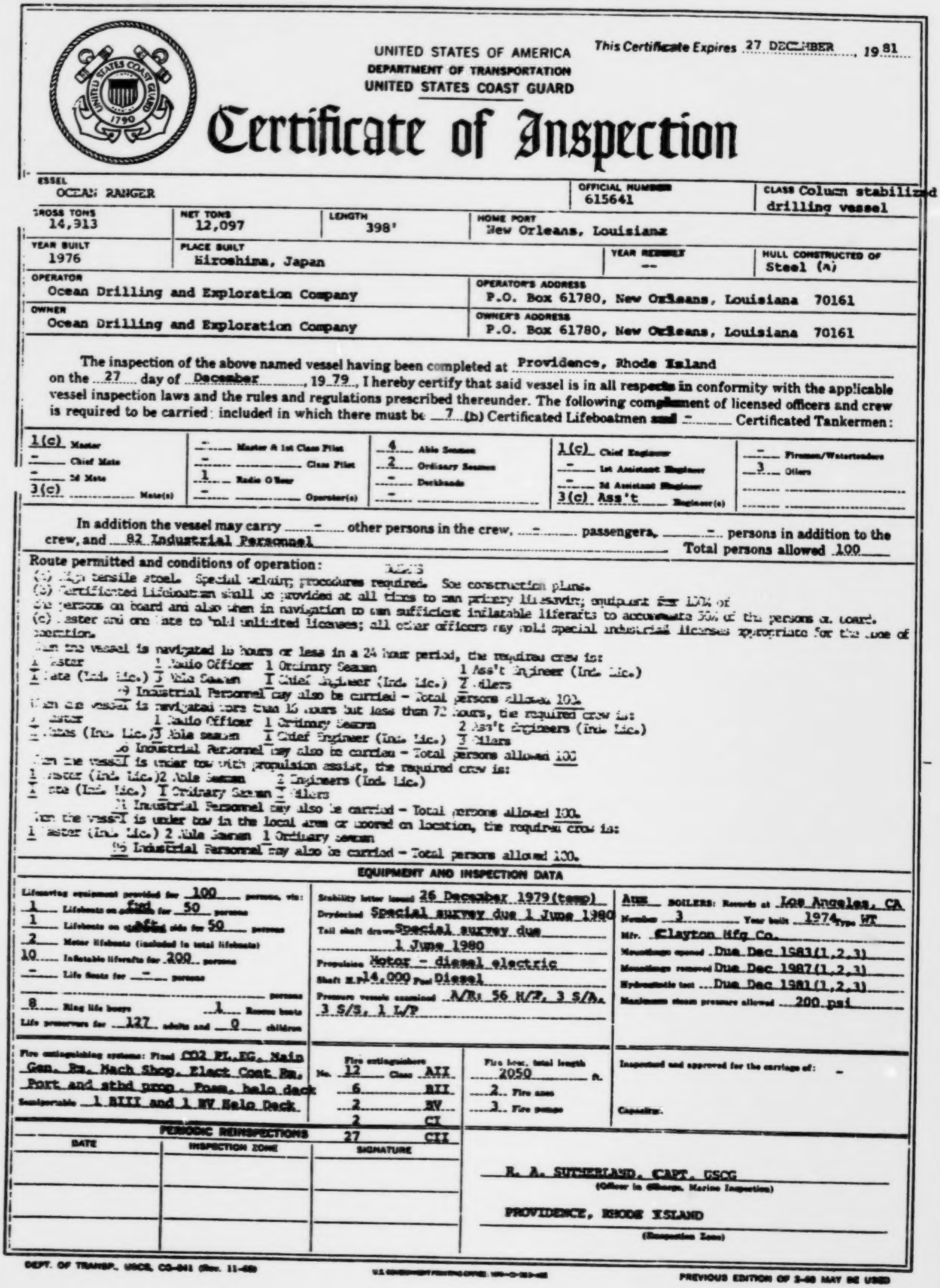
[8] Write "said register", "said enrollment", or "said license." In the first document of a new vessel, give the name and title of the admeasurer. When the vessel has been readmeasured, give the name and title of the admeasurer in the first document issued thereafter.

[9] For a vessel having a steam (or an internal combustion) engine, write "steam (or gas or oil) side-wheel", "steam (or gas or oil) stern-wheel," "steam (or gas or oil) screw," as case may be.

[10] Insert dimensions and tonnages exactly as they appear on the preceding document (or the certificate of admeasurement in case of a change in tonnage or upon issuance of the first document).

[11] Give the name of the person agreeing to the description and measurement and the capacity in when he acts (owner.

Item C-3



UNITED STATES OF AMERICA
DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

This Certificate Expires 27 DECEMBER, 1981

Certificate of Inspection

VESSEL: OCEAN RANGER
OFFICIAL NUMBER: 615641
CLASS: Column stabilized drilling vessel
GROSS TONS: 14,913
NET TONS: 12,097
LENGTH: 398'
HOME PORT: New Orleans, Louisiana
YEAR BUILT: 1976
PLACE BUILT: Hiroshima, Japan
YEAR REBUILT: --
HULL CONSTRUCTED OF: Steel (A)
OPERATOR: Ocean Drilling and Exploration Company
OPERATOR'S ADDRESS: P.O. Box 61780, New Orleans, Louisiana 70161
OWNER: Ocean Drilling and Exploration Company
OWNER'S ADDRESS: P.O. Box 61780, New Orleans, Louisiana 70161

The inspection of the above named vessel having been completed at Providence, Rhode Island on the 27 day of December, 1979, I hereby certify that said vessel is in all respects in conformity with the applicable vessel inspection laws and the rules and regulations prescribed thereunder. The following complement of licensed officers and crew is required to be carried: included in which there must be 7 (b) Certificated Lifeboatmen and - Certificated Tankermen:

1(c) Master	- Master & 1st Class Pilot	4 Able Seamen	1(c) Chief Engineer	- Firemen/Watertenders
- Chief Mate	- Class Pilot	2 Ordinary Seamen	- 1st Assistant Engineer	3 Oilers
- 2d Mate	1 Radio O'ficer	- Deckhands	- 2d Assistant Engineer	
3(c) Mate(s)	- Operator(s)	-	3(c) Ass't Engineer(s)	

In addition the vessel may carry - other persons in the crew, - passengers, - persons in addition to the crew, and 82 Industrial Personnel Total persons allowed 100

Route permitted and conditions of operation: NOTES
(a) High tensile steel. Special welding procedures required. See construction plans.
(b) Certificated Lifeboatmen shall be provided at all times to man primary lifesaving equipment for 100% of the persons on board and also when in navigation to man sufficient inflatable liferafts to accommodate 50% of the persons on board.
(c) Master and one Mate to hold unlimited licenses; all other officers may hold special industrial licenses appropriate for the mode of operation.
When the vessel is navigated 16 hours or less in a 24 hour period, the required crew is:
1 Master 1 Radio Officer 1 Ordinary Seaman 1 Ass't Engineer (Ind. Lic.)
1 Mate (Ind. Lic.) 3 Able Seamen 1 Chief Engineer (Ind. Lic.) 2 Oilers
89 Industrial Personnel may also be carried - Total persons allowed 100.
When the vessel is navigated more than 16 hours but less than 72 hours, the required crew is:
1 Master 1 Radio Officer 1 Ordinary Seaman 2 Ass't Engineers (Ind. Lic.)
2 Mates (Ind. Lic.) 3 Able seamen 1 Chief Engineer (Ind. Lic.) 3 Oilers
86 Industrial Personnel may also be carried - Total persons allowed 100
When the vessel is under tow with propulsion assist, the required crew is:
1 Master (Ind. Lic.) 2 Able Seamen 2 Engineers (Ind. Lic.)
1 Mate (Ind. Lic.) 1 Ordinary Seaman 1 Oilers
91 Industrial Personnel may also be carried - Total persons allowed 100.
When the vessel is under tow in the local area or moored on location, the required crew is:
1 Master (Ind. Lic.) 2 Able Seamen 1 Ordinary seaman
96 Industrial Personnel may also be carried - Total persons allowed 100.

EQUIPMENT AND INSPECTION DATA

Lifesaving equipment provided for 100 persons, viz:
1 Lifeboats on fwd for 50 persons
1 Lifeboats on aft side for 50 persons
2 Motor lifeboats (included in total lifeboats)
10 Inflatable liferafts for 200 persons
- Life floats for - persons
8 Ring life buoys 1 Rescue boats
Life preservers for 127 adults and 0 children

Stability letter issued 26 December 1979 (temp)
Drydocked Special survey due 1 June 1980
Tail shaft drawn Special survey due 1 June 1980
Propulsion Motor - diesel electric
Shaft H.P. 14,000 Fuel Diesel
Pressure vessels examined A/R: 56 H/P, 3 S/A, 3 S/S, 1 L/P

Aux BOILERS: Records at Los Angeles, CA
Number 3 Year built 1974 Type WT
Mfr. Clayton Mfg Co.
Mountings opened Due Dec 1983 (1,2,3)
Mountings removed Due Dec 1987 (1,2,3)
Hydrostatic test Due Dec 1981 (1,2,3)
Maximum steam pressure allowed 200 psi

Fire extinguishing systems: Fixed CO2 PL, EG, Main Gen. Rm, Mach Shop, Elect Cont Rm, Port and stbd prop. Foam, helo deck
Semiportable 1 BIII and 1 BV Helo Deck

Fire extinguishers No.	Class
12	AII
6	BII
2	BV
2	CI
27	CII

Fire hose, total length 2050 ft.
2 Fire axes
3 Fire pumps

Inspected and approved for the carriage of: -
Capacity:

PERIODIC REINSPECTIONS

DATE	INSPECTION ZONE	SIGNATURE

R. A. SUTHERLAND, CAPT. USCG
(Officer in Charge, Marine Inspection)

PROVIDENCE, RHODE ISLAND
(Inspection Zone)

DEPT. OF TRANSP., USCG, CG-841 (Rev. 11-68)

U.S. GOVERNMENT PRINTING OFFICE

PREVIOUS EDITION OF 3-68 MAY BE USED

This Certificate Expires 27 December , 19 81

UNITES STATES OF AMERICA
DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

CERTIFICATE OF INSPECTION

VESSEL OCEAN RANGER	OFFICIAL NUMBER 615641	CLASS Column stabilized drilling vessel

GROSS TONS 14,913	NET TONS 12,097	LENGTH 398'	HOME PORT New Orleans, Louisiana

YEAR BUILT 1976	PLACE BUILT Hiroshima, Japan	YEAR REBUILT –	HULL CONSTRUCTED OF Steel (a)

OPERATOR Ocean Drilling and Exploration Company	OPERATOR'S ADDRESS P.O. Box 61780, New Orleans, Louisiana 70161
OWNER Ocean Drilling and Exploration Company	OWNER'S ADDRESS P.O. Box 61780, New Orleans, Louisiana 70161

The inspection of the above named vessel having been completed at Providence, Rhode Island on the 27 day of December , 19 79 , I hereby certify that said vessel is in all respects in conformity with the applicable vessel inspection laws and the rules and regulations prescribed thereunder The following complement of licensed officers and crew is required to be carried; included in thich there must be 7(b) Certificated Lifeboatmen and – Certificated Tankermen:

1(c)	Master	—	Master & 1st Class Pilot	4	Able Seamen	1(c)	Chief Engineer	—	Firemen/Watertenders
—	Chief Mate	—	Class Pilot	2	Ordinary Seamen	—	1st Assistant Engineer	3	Oilers
—	2d Mate	1	Radio Officer	—	Deckhands	—	2d Assistant Engineer		
3(c)	Mate(s)	—	Operator(s)	—		3(c)	Ass't Engineer(s)		

In addition the vessel may carry — other persons in the crew, — passengers, — persons in addition to the crew, and 82 Industrial Personnel Total Persons allowed 100 .

Route permitted and conditions of operation: OCEANS

(a) High tensile steel. Special welding procedures required. See construction plans.

(b) Certificated Lifeboatmen shall be provided at all times to man primary lifesaving equipment for 100% of the persons on board and also when in navigation to man sufficient inflatable liferafts to accomodate 50% of the persons on board.

(c) Master and one Mate to hold unlimited licenses; all other officers may hold special industrial licenses appropriate for the mode of operation.

When the vessel is navigated 16 hours or less in a 24 hour period, the required crew is:

1 Master	1 Radio Officer	1 Ordinary Seamen	1 Ass't Engineer (Ind. Lic.)
1 Mate (Ind. Lic.)	3 Able Seamen	1 Chief Engineer (Ind. Lic.)	2 Oilers

89 Industrial Personnel may also be carried — Total persons allowed 100

When the vessel is navigated more than 16 hours but less than 72 hours, the required crew is:

1 Master	1 Radio Officer	1 Ordinary Seamen	2 Ass't Engineers (Ind. Lic.)
2 Mates (Ind. Lic.)	3Able Seamen	1 Chief Engineer (Ind. Lic.)	3 Oilers

86 Industrial Personnel may also be carried — Total persons allowed 100.

When the vessel is under tow with propulsion assist, the required crew is:

1 Master (Ind. Lic.)	2 Able Seamen	2 Engineers (Ind. Lic.)
1 Mate (Ind. Lic.)	1 Ordinary Seaman	2 Oilers

91 Industrial Personnel may also be carried — Total persons allowed 100.

When the vessel is under tow in the local area or moored on location, the required crew is:

1 Master (Ind. Lic.)	2 Able Seamen	1 Ordinary Seaman

96 Industrial Personnel may also be carried — Total persons allowed 100.

EQUIPMENT AND INSPECTION DATA

Lifesaving equipment provided for 100 persons, viz:
1 Lifeboats on fwd for 50 persons
1 Lifeboats on aft side for 50 persons
2 Motor Lifeboats (included in total lifeboats)
10 Inflatable liferafts for 200 persons
— Life floats for — persons
persons
8 Ring life buoys 1 Rescue boats
Life preservers for 127 adults and 0 children

Stability letter issued 26 December 1979 (temp)
Drydocked Special survey due 1 June 1980
Tail shaft drawn Special survey due 1 June 1980
Propulsion Motor — diesel electric
Shaft H.P. 14,000 Fuel Diesel
Pressure vessels examined A/R: 56 H/P, 3 S/A, 3 S/S, 1 L/P

Aux BOILERS: Records at Los Angeles, CA
Number 3 Year built 1974 Type WT
Mfr. Clayton Mfg. Co.
Mountings opened Due Dec 1983 (1,2,3)
Mountings removed Due Dec 1987 (1,2,3)
Hydrostatic test Due Dec 1981 (1,2,3)
Maximum steam pressure allowed 200 psi

Fire extinguishing systems: Fixed C02 PL, EG, Main Gen. Rm. Mach Shop, Elect Cont Rm, Port and stbd prop. Foam, helo deck
Semiportable 1 BIII and 1 BV Helo Deck

Fire extinguishers

No.	Class
12	AII
6	BII
2	BV
2	CI

Fire hose, total length 2050 ft.
2 Fire axes
3 Fire pumps

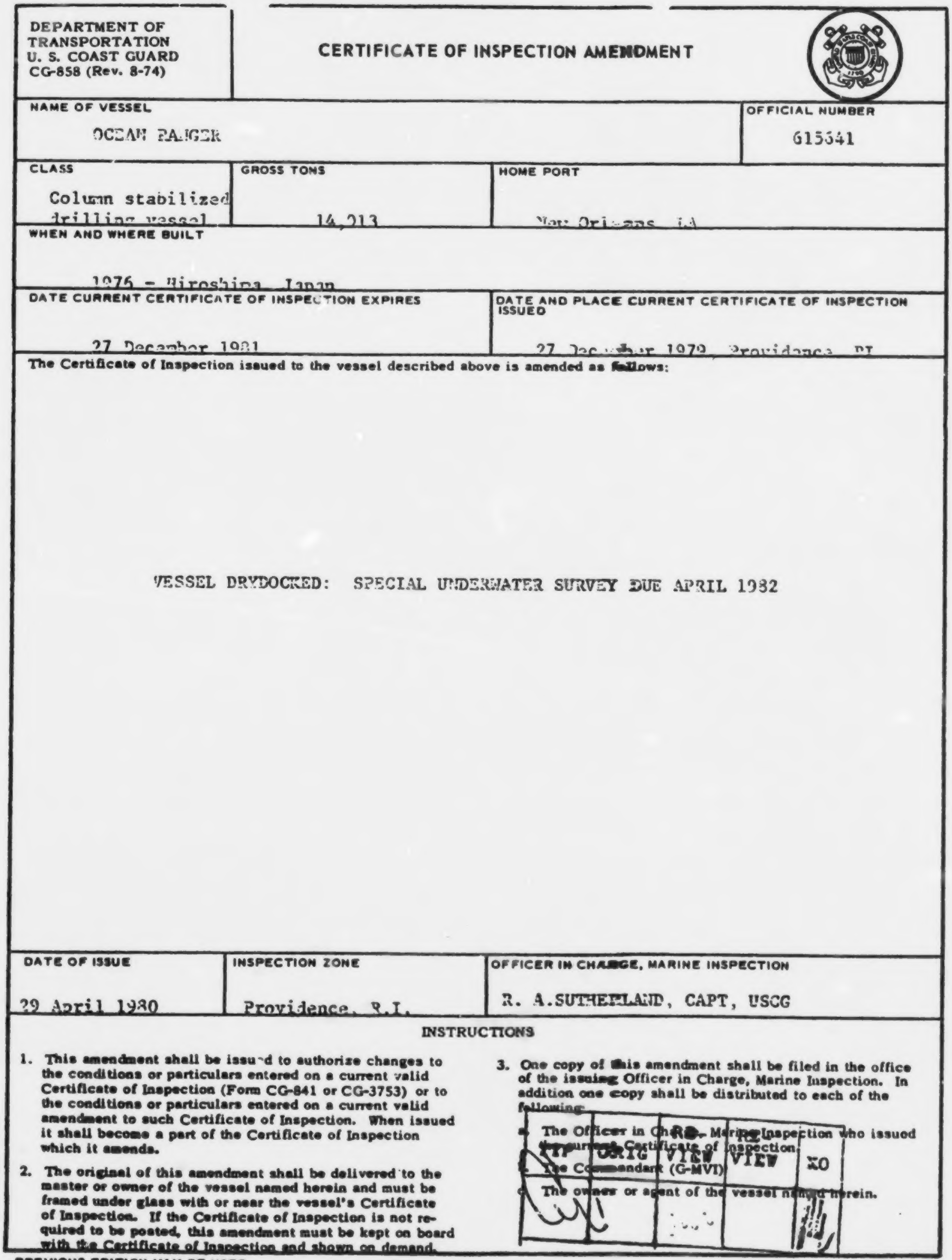
Inspected and approved for the carriage of:

Capacity:

	PERIODIC INSPECTIONS	27 CII
DATE	INSPECTION ZONE	SIGNATURE

R. A. SUTHERLAND, CAPT. USCG
(Officer in Charge, Marine Inspection)-
PROVIDENCE, RHODE ISLAND
(Inspection Zone)

DEPT. OF TRANSP., USCG, CG-841 (Rev. 11-68) U.S. GOVERNMENT PRINTING OFFICE 1968-0-363-482 PREVIOUS EDITION OF 2-68 MAY BE USED



DEPARTMENT OF
TRANSPORTATION
U. S. COAST GUARD
CG-858 (Rev. 8-74)

CERTIFICATE OF INSPECTION AMENDMENT

NAME OF VESSEL
OCEAN RANGER

OFFICIAL NUMBER
615641

CLASS
Column stabilized drilling vessel

GROSS TONS
14,913

HOME PORT
New Orleans, LA

WHEN AND WHERE BUILT
1976 - Hiroshima, Japan

DATE CURRENT CERTIFICATE OF INSPECTION EXPIRES
27 December 1981

DATE AND PLACE CURRENT CERTIFICATE OF INSPECTION ISSUED
27 December 1979, Providence, RI

The Certificate of Inspection issued to the vessel described above is amended as follows:

VESSEL DRYDOCKED: SPECIAL UNDERWATER SURVEY DUE APRIL 1982

DATE OF ISSUE
29 April 1980

INSPECTION ZONE
Providence, R.I.

OFFICER IN CHARGE, MARINE INSPECTION
R. A.SUTHERLAND, CAPT, USCG

INSTRUCTIONS

1. This amendment shall be issued to authorize changes to the conditions or particulars entered on a current valid Certificate of Inspection (Form CG-841 or CG-3753) or to the conditions or particulars entered on a current valid amendment to such Certificate of Inspection. When issued it shall become a part of the Certificate of Inspection which it amends.
2. The original of this amendment shall be delivered to the master or owner of the vessel named herein and must be framed under glass with or near the vessel's Certificate of Inspection. If the Certificate of Inspection is not required to be posted, this amendment must be kept on board with the Certificate of Inspection and shown on demand.
3. One copy of this amendment shall be filed in the office of the issuing Officer in Charge, Marine Inspection. In addition one copy shall be distributed to each of the following:
   - a. The Officer in Charge, Marine Inspection who issued the current Certificate of Inspection.
   - b. The Commandant (G-MVI)
   - c. The owner or agent of the vessel named herein.

TYP	ORIG	RE-VIEW	RE-VIEW	XO

PREVIOUS EDITION MAY BE USED

GPO 956-511

DEPARTMENT OF
TRANSPORTATION
U.S. COAST GUARD
CG-858 (Rev. 8-74)

CERTIFICATE OF INSPECTION AMENDMENT

NAME OF VESSEL OCEAN RANGER		OFFICIAL NUMBER 615641
CLASS Column stabilized drilling vessel	GROSS TONS 14,913	HOME PORT New Orleans, LA

WHEN AND WHERE BUILT
1976 – Hiroshima, Japan

DATE CURRENT CERTIFICATE OF INSPECTION EXPIRES 27 December 1981	DATE AND PLACE CURRENT CERTIFICATE OF INSPECTION ISSUED 27 December 1979, Providence, RI

The Certificate of Inspection issued to the vessel described above is amended as follows:

VESSEL DRYDOCKED: SPECIAL UNDERWATER SURVEY DUE APRIL 1982

DATE OF ISSUE 29 April 1980	INSPECTION ZONE Providence, RI	OFFICER IN CHARGE, MARINE INSPECTION R. A. SUTHERLAND, CAPT, USCG

INSTRUCTIONS

1. This amendment shall be issued to authorize changes to the conditions or particulars entered on a current valid Certificate of Inspection (Form CG-841 or CG-3753) or to the conditions or particulars entered on a current valid amendment to such Certificate of Inspection. When issued it shall become a part of the Certificate of Inspection which it amends.
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3. One copy of this amendment shall be filed in the office of the issuing Officer in Charge, Marine Inspection. In addition one copy shall be distributed to each of the following:
   a. The Officer in Charge, Marine Inspection who issued the current Certificate of Inspection.
   b. The Commandant (G-MVI).
   c. The owner or agent of the vessel named herein.

PREVIOUS EDITION MAY BE USED

GPO 956-511

Item C-4
Certificates Issued for the *Ocean Ranger*

1. THE CERTIFICATE OF INSPECTION was issued at Providence, Rhode Island by the United States Coast Guard on December 27, 1979, and expired December 27, 1981.

2. THE CERTIFICATE OF CARGO SHIP SAFETY EQUIPMENT was issued at Providence, Rhode Island by the United States Coast Guard on December 27, 1980, and expired December 27, 1981.

3. THE INTERNATIONAL LOAD LINE SURVEY CERTIFICATE, was issued at New York by the American Bureau of Shipping on behalf of the United States Coast Guard on October 30, 1981, under the provisions of the International Convention on Loadlines 1966. The certificate was valid until July 5, 1984 subject to annual survey.

4. THE CARGO SHIP SAFETY CONSTRUCTION CERTIFICATE was issued at New York by the American Bureau of Shipping on April 28, 1980, under the provisions of the International Convention for Safety of Life at Sea, 1960, and was valid until July 31, 1984.

5. THE CARGO SHIP SAFETY RADIO TELEGRAPHY CERTIFICATE was issued at St. John's, Newfoundland, by the American Bureau of Shipping, under the Authority of the Government of Canada on April 16, 1981, under the provisions of the International Convention for Safety of Life at Sea, 1974, and expired April 15, 1982. No exemption was given from the requirement that a continuous watch be kept on 2182 Mkz.

6. ANNUAL CLASS SURVEY, (Hull and Machinery), Annual Load Line Inspection, Annual Cargo Gear Inspection and extension of Tailshaft Survey (Port and Starboard) performed by the American Bureau of Shipping, June 16, 1981, on location off St. John's, Newfoundland. Certificate issued from Halifax, Nova Scotia.

Item C-5
Correspondence Regarding MODU *Ocean Ranger* Inspection for U.S. Certification

Officer in Charge
Marine Inspection Office
John O. Pastore Fed. Bldg.
Providence, RI 02903
Tel.: 401-528-4335

16711
18 December 1979

Ocean Drilling & Exploration Co.
P.O. Box 61780
New Orleans, LA 70161

Attention: Dr. Terry Petty

Subj: MODU *OCEAN RANGER*
398' x 262' x 151' Semi-Submersible Drilling Unit
Non-Classed
Inspection for Certification

Gentlemen:

An initial inspection was conducted on subject drilling unit from 4 through 14 December 1979. The following items are required to be completed prior to issuing a U.S. Coast Guard Certificate of Inspection:

1. Provide an FCC certificate for radios (vessels and lifeboat)
2. Provide and install an Emergency Position Indicating Radio Beacon (EPIRB)
3. Provide certificate of servicing for portable fire extinguishers
4. Provide two (2) firemens' outfits
5. Stencil lifejacket lockers and remote fuel shutoffs
6. Test number 2 boiler low water cutout
7. Provide adequate MESA approved first aid kit for 100 persons
8. Register vessel as a U.S. vessel (obtain Official Number)

The following items to be completed prior to 15 January 1980 or issuance of Certificate of Inspection, whichever is later:

1. Provide CG approved ring buoys (8 required)
2. Provide CG approved lifeboat provisions for both lifeboats
3. Provide two CG approved smoke floats to be attached to ring buoys
4. Paint helicopter landing deck with non-skid paint
5. Mark general alarm with signs as per 46 CFR 108.625
6. Mark C02 alarms with signs as per 108.627
7. Mark liferafts with signs as per 108.655
8. Inspect and repair fire detection system
9. Add an adequate vent for the C02 room
10. Provide wind direction indicator for helo deck
11. Mark access to helo deck with warning signs (all three accesses)
12. Replace interior fire hose with CG approved hose and CG approved combination nozzles (alter system to receive these hoses)
13. Provide International shore connection
14. Post fueling procedures
15. Comply with marine portable tank (MPT) regs.
16. Operate foam system take a sample and have it analyzed

To be accomplished prior to bringing fuel aboard for helicopter refuelling:

1. Install remote fuel pump shutdown at main access
2. Mark fuel hose storage in accordance with regulation
3. Make visible the fuel pump operation indicator light

To be accomplished prior to 1 June 1980 or issuance of Certificate of Inspection, whichever is later:

1. Install a second radar independently powered from the existing one
2. Submit for review by the Commandant, USCG, plans for special survey of underwater body, and accomplish special survey as required
3. Submit for review and obtain approval of Fire Control and Safety Plan

To be done prior to next Inspection for Certification:

1. Comply with 46 CFR 108.506 davit launched liferafts or acceptable substitute
2. Replace lifeboats and davits with CG approved or obtain approval for existing ones
3. Obtain approval of fixed CO2 system
4. Obtain CG approval of fire detection system

All above items to be completed to the satisfaction of the cognizant Officer in Charge, Marine Inspection.

Sincerely,

R.A. SUTHERLAND
Captain, U.S. Coast Guard
Officer in Charge,
Marine Inspection

Item C-6
COGLA'S Directive to Offshore Operators Regarding Survival Suits

NOTE: All telexes contained in the Appendix are reproduced as entered in evidence. Typographical errors are reproduced from the originals.

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SHELL CNTR CGY
EMR RMCB OTT

NOTICE TO OPERATORS

SURVIVAL SUITS FOR EXPLORATION VESSELS

BECAUSE OF THE COLD WATERS COMMON TO CANADIAN OFFSHORE EXPLORATION REGIONS, IT IS APPARENT THAT SURVIVAL SUITS ARE AS IMPORTANT AS LIFE JACKETS FOR THE SAFETY OF PERSONNEL ON BOARD EXPLORATION VESSELS. MORE LIVES MAY HAVE BEEN SAVED DURING THE RECENT LOSS OF THE *ARCTIC EXPLORER* HAD SURVIVAL SUITS BEEN AVAILABLE.

WHILE IT WILL NOT BE A STRICT REQUIREMENT DURING THIS YEAR'S EXPLORATION SEASON, ALL OPERATORS SHOULD HAVE A SURVIVAL SUIT FOR EACH PERSON ABOARD A DRILLING UNIT, SUPPLY VESSEL AND GEOPHYSICAL VESSEL AS SOON AS PRACTICAL.

IT IS A MOOT POINT WHETHER DONNING OF THE SURVIVAL SUIT SHOULD BE PART OF THE LIFEBOAT DRILL. IN AN ACTUAL EMERGENCY IT COULD BE LEFT TO THE INDIVIDUAL JUDGEMENT WHETHER THE SURVIVAL SUIT BE PUT ON BEFORE THE LIFE JACKET. IN ANY EVENT IT IS IMPORTANT THAT THE SUITS BE AVAILABLE FOR USE IF TIME PERMITS. IT IS RECOMMENDED THAT THE SUITS BE STORED AT SEVERAL POINTS ON THE VESSEL ADJACENT TO PRINCIPAL MANWAYS AND AT THE LIFEBOAT STATIONS.

THE TYPE OF SUIT RECOMMENDED IS THE LIGHTWEIGHT MULTI-FAB DRY TYPE WHICH CAN READILY FIT UNDER A LIFE JACKET. ANY COMMENTS YOU MAY HAVE ON THIS REQUIREMENT SHOULD BE DIRECTED TO OTTAWA. PHONE (613) 993-3760 OR TELEX NO 053-4366.

FREDERICK LEPINE
CONSERVATION ENGINEER
CANADA OIL AND GAS LANDS ADMINISTRATION

July 7, 1981

ATTN: E. HOPKINS

•

SHELL CNTR CGY

SHELL CNTR CGY
EMR RMCB OTT

SURVIVAL SUITS FOR EXPLORATORY VESSELS ON CANADA LANDS

FURTHER TO TELEX OF JULY 7, 1981 CONCERNING THE PROVISION OF SURVIVAL SUITS FOR ALL PERSONNEL ABOARD EXPLORATION VESSELS ON CANADA LANDS, INITIAL COMMENT FROM INDUSTRY SUGGESTS TWO TYPES OF SUITS COULD BE SUITABLE.

A. A LIGHT-WEIGHT MOISTURE PROOF SUIT WITH GOOD THERMAL INSULATION. A LIFE-JACKET WOULD BE A NECESSARY SUPPLEMENT. THESE SUITS DO NOT REQUIRE MUCH STORAGE SPACE AND ALLOW THE WEARER GREATER FREEDOM OF MOVEMENT. THEY ARE PARTICULARLY SUITABLE FOR HELICOPTER FLIGHTS AND FOR WORKING SITUATIONS SUCH AS THE DECK OF A SUPPLY OR SEISMIC VESSEL.

B. THE CANADIAN COAST GUARD FAVOURS AND APPROVES AN INSULATED BUOYANT IMMERSION SUIT THAT INCLUDES COVERING FOR THE HANDS AND FEET AND PROVIDES BUOYANCY WITH HYPOTHERMIC PROTECTION. THE CANADIAN COAST GUARD HAS ESTABLISHED SPECIFICATIONS FOR THIS TYPE OF SUIT INCLUDING THE REQUIREMENT THAT IT BE PUT ON IN ONE MINUTE. THESE SUITS IN GENERAL PROVIDE BETTER THERMAL PROTECTION AND ARE BEST FOR ACCOMMODATION VESSELS, CREW QUARTERS AND ARTIFICIAL ISLANDS.

YOU ARE INVITED TO PROVIDE FURTHER COMMENT TO MYSELF OR DR. JAN MERTA AT OTTAWA (613) 993-3760 OR TELEX 053 4366.

F.H. LEPINE
CHIEF
DRILLING AND OPERATIONS
OPERATIONS AND CONSERVATION DIVISION
RESOURCE MANAGEMENT
CANADA OIL AND GAS LANDS ADMINISTRATION
OTTAWA

July 28, 1981

The 2 preceding telexes were sent to the following:

cc:	Shell Calgary	Attention: E. Hopkin Telex no.		038 24792
	Petro-Canada Calgary	Attention: D. Duff		038 27574
	Petro-Canada St. John's	Attention: G. Lever		016 4027
	Mobil Oil Dartmouth	Attention: Mathews		019 22580
	Mobil Oil St. John's	Attention: S. Romansky		016 4145
	BP Canada Calgary	Attention: Alan Ace		038 24782
	Chevron Standard Calgary	Attention: R. Richardson L. Zerr		038 21645
	H B O G Calgary	Attention: K. Putnam		038 21794
	RMB Dartmouth			019 31557
	RMB St. John's			016 4031
	DINA Hull	Attention: T. Starr		3711
	DINA Yellowknife	Attention: M. Smith		034 45519
	Dome Calgary	Attention: S. Montgomery B. Barnard		038 22626
	Dome Tuk	Attention: L. Prather		031 44508
	Gulf Calgary	Attention: C.E. Fidler R.P Coté		038 24551
	Esso Resources Calgary	Attention: Ron Royal H. Sangster		038 24534
	CCG MUT Ottawa	Attention: B.D. Thorne		053 3128
	CPA Calgary	Attention: Mr. Smyth	Telecopier	261 4622
	IPAC Calgary	Attention: J. Porter	Telecopier	261 4059

SHELL CNTR CGY
EMR RMCB OTT

OPERATIONS

APPENDIX D

APPENDIX D

OPERATIONS

1. OPERATING HISTORY OF THE *OCEAN RANGER* June 30, 1976 to February 14, 1982. 229
2. BACKGROUND INFORMATION ON KEY PERSONNEL ON BOARD THE *OCEAN RANGER* February 15, 1982. 230
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4. *OCEAN RANGER* STABILITY CALCULATION FORMS Extract from the Booklet of Operating Conditions January 6, 1981. Exhibit #51A. 232

Item D-1
Operating History of the *Ocean Ranger*

DATES	OPERATOR	LOCATION
May, 1976		Launching from No. 2 Eba Shipyard of Mitsubishi Heavy Industries, Japan
June 3, 1976	ARCO	Mobilizing from MHI Shipyard in Japan to Alaska
June 26, 1976	ARCO	Cost No. 1, St. George
October 1, 1976	ARCO	Mobilizing from Bering Sea to Gulf of Alaska
October 15, 1976	ARCO	Splome No. 1, Block 72 – Gulf of Alaska
June 3, 1977	ARCO	Mobilizing from Gulf of Alaska – Lower Cook Inlet
June 9, 1977	ARCO	Lower Cook Inlet, Cost No. 1
September 27, 1977	IDLE	Stand by – Lower Cook Inlet
March 12, 1978	IDLE	Mobilizing from Lower Cook Inlet to Resurrection Bay
March 15, 1978	IDLE	Stand by – Seaward Resurrection Bay
December 4, 1978	IDLE	Mobilizing from Resurrection Bay to Port Alberni, B.C.
December 14, 1978	REPAIRS	Stand by – Port Alberni Harbour, B.C.
August 5, 1979	–	Mobilizing from Port Alberni, B.C. to Baltimore Canyon via Straits of Magellan and Narragansett Bay
December 16, 1979	Murphy	Baltimore Canyon, Block 106
May 29, 1980	Philips	Mobilizing from Baltimore Canyon to Ireland
June 17, 1980	Philips	Offshore Ireland
October 20, 1980	Mobil	Mobilizing from Ireland to Newfoundland
November 6, 1980	Mobil	G-55 Hibernia, Newfoundland
February 24, 1981	Mobil	K-18 Hibernia, Newfoundland
June 7, 1981	Mobil	J-87 Hibernia, Newfoundland
November 24, 1981 – February 15, 1982	Mobil	J-34 Hibernia, Newfoundland

Item D-2
Background Information on Key Personnel

I. TOOLPUSHER

The Toolpusher on the *Ocean Ranger* was Benjamin Kent Thompson. Thompson was a United States citizen with approximately 15 years experience in the drilling industry. Mr. Thompson initially joined ODECO in 1974 as a floorman and worked on the *Margaret*. In November 1974, he was rehired by ODECO as a floorman and was assigned to the *Ocean Explorer*. He was promoted to Driller in 1978 and to Toolpusher June 1979. As a Toolpusher, he worked on several ODECO rigs including the *Ocean Patriot*, *Ocean Champion*, and *St. Louis*. He was assigned to the *Ocean Ranger* in January 1981 as Toolpusher. Thompson had no formal marine certification from the United States Coast Guard. He attended a Blowout Prevention course at the University of Oklahoma and several in-house ODECO training courses on well control and rig management.

II. MASTER

The Master was Captain Clarence Hauss. Captain Hauss was a United States citizen and held a valid United States Coast Guard licence as Master of Steam and Motor Vessels, Any Gross Tons Upon Oceans. Captain Hauss was employed as a Master and Chief Mate with Bethlehem Steel Corporation from 1956 to 1971. He joined ODECO on March 31, 1981 and was assigned to the *Ocean Victory*. However, during the 10-year period prior to joining ODECO, Captain Hauss worked as a stevedoring superintendent, as a technician in a detoxification centre and as a salesman. He was not active as a Master Mariner. Before joining the *Ocean Ranger* as Master on January 26, 1982, he had served three hitches (28 days/hitch) on the *Ocean Victory* and one hitch on the *Ocean Bounty*.

III. DRILLING FOREMAN

The Senior Mobil Drilling Foreman was Jack Jacobsen, a Canadian citizen who had 16 years experience in the drilling industry. He was 39 years old. In 1966 he began working as a derrickman with Kenting Drilling. In 1971/72 he worked as derrickman and driller with Garnet Drilling. He worked as a driller with Nabors Drilling in 1972/73, and in 1973 he joined SEDCO where he was promoted to Assistant Superintendent in 1974. He remained with SEDCO until 1980 when he joined Mobil as a Drilling Foreman. He had a grade 10 education and had completed courses in Blowout Prevention and Applied Drilling Techniques.

IV. BALLAST CONTROL OPERATORS

The Senior Ballast Control Operator was Donald Rathbun, a United States citizen. He joined ODECO in January 1980, with no previous experience in the drilling industry, either on land or offshore. In March 1980, he was promoted from Roustabout to Ballast Control Operator. Mr. Rathbun's employment with ODECO was entirely on the *Ocean Ranger*. He did not hold any formal marine licences and had not attended any formal ODECO training programs in the ballast control area.

The Junior Ballast Control Operator was Domenic Dyke, a Canadian citizen. Before joining ODECO as a Roustabout in December 1980, he worked with SEDCO as a Roustabout and with Crosbie Offshore Services as a Deckhand on supply vessels. He was promoted from Roustabout to Ballast Control Operator on December 31, 1981, and was serving his second hitch as a Ballast Control Operator at the time of the casualty.

V. RIG ELECTRICIANS

The Senior Electrician was Thomas Donlon, a United States citizen. He had extensive experience as an Electrician and had been assigned to the *Ocean Ranger* since 1977.

Paul Bursey, a Canadian citizen, was the second Electrician on the *Ocean Ranger*. He joined ODECO in June 1981 and was assigned to the *Ocean Ranger*. Prior to joining ODECO, he was employed as a Marine Electrician with Canadian National for seven years.

VI. RIG MECHANIC

The Rig Mechanic was George Gandy, a United States citizen. Gandy had extensive experience in the drilling industry on land and offshore in the Gulf of Mexico, the North Sea, and off West Africa. He joined ODECO as a Rig Mechanic and was assigned to the *Ocean Ranger* in February 1977 for a period of seven months. He was reassigned to the *Ocean Ranger* in March 1980. He held an Ordinary Seaman's ticket issued by the United States Coast Guard.

VII. ELECTRONICS TECHNICIAN

The Electronics Technician was Ted Stapleton, a Canadian citizen. He had completed a 5 year Electronics program at the College of Trades and Technology St. Johns, Newfoundland and received apprenticeship training with the Iron Ore Company of Canada. He had 15 years onshore experience in electronics, prior to joining ODECO in May of 1981. He had experience as a Radio Officer with the Canadian Coast Guard.

It was not possible to obtain background information on several other ODECO employees who were assigned to the *Ocean Ranger* at the time of the casualty. At the time of writing, ODECO had not provided these personnel records.

Item D-3
Communications Equipment On board the *Ocean Ranger*

1 Ship's Radio Systems

a) ITT MRU 29B main and reserve transmitters, receivers, auto alarm receiver, auto alarm keyer, antenna switch, power supplies, battery charger and batteries.

b) VHF marine radios:
   a) Decca, ITT STR – 24
   b) Motorola, D33ADA1019AK

c) EPIRB – AKC Electronics, ACR/RLB 14

2 H.F. Radio Systems

a) Communications Associated, Inc. model CA35MS with CL36 amplifier. Frequency range: 2-30 MHZ. Power output: 1,000 watts.

b) Communications Associates, Inc. model CA 35MS. Frequency: 2-30 MHZ. Power output: 100 watts. Two-tone alarm: Honeywell TG502. Power: battery or ship's power.

c) R.F. Harris Co. Model RF230MAC. Frequency: 2-30 MHZ. Power output: 100 watts.

3 Miscellaneous Communications Systems

a) CAI model CR19/C754 VHF aircraft radio. Frequency: 122.00 MHZ. Power: 50 watts. Emission: A3A

b) Scientific Atlanta MARISAT Terminal.

c) Southern Avionics Aircraft Beacon, Model SS800.

Item D-4
Ocean Ranger Stability Calculation Forms.

CONDITION:	LOADING TABLE 1. OPERATIONAL LIGHTWEIGHT								
ITEM	WEIGHT L. TONS	VCG FT.	VERTICAL MOMENT L.T.X FT.	VCG FT.	LONGL. MOMENT L. TONS X FT.		TCG FT.	TRANSVERSE MOMENT L. TONS X FT.	
					+AFT	-FWD		-PORT	+STBD
LIGHTWEIGHT (Excluding all movable anchoring gear, and excluding all operating liquids: traveling gear in highest position).	20,881.3	86.92	1,814,905	4.99 A	104,224		1.11 S		23,191
TRAVELING GEAR LOWERED. LT.									
MOORING EQUIPMENT:-									
Wire 12 @ Ft. - 3 1/2"(22.9 #/Ft.)									
Cable 12 @ Ft. - 3 1/4"(105.1 #/Ft.)									
Anchors 12 @ 45,000 # ea.									
Chain connector links.									
Mooring pull down (C 21)									
OPERATING LIQUIDS (TRANSIT) (B 21)									
OPERATIONAL LIGHTWEIGHT									

LOADING TABLE 2A BULK AND SACK STORAGE										
MAXIMUM CAPACITY L. TONS.	ITEM	ACTUAL WEIGHT L. TONS	VCG FT.	VERTICAL MOMENT LT X FT	LCG FT.	LONGL. MOMENT LT. X FT.		TCG FT.	TRANS. MOMENT LT. X FT.	
						+AFT	-FWD		-PORT	+STBD
a 34.4	Bulk Tank #1 820 cu.ft.		142.39		-100.92	-		-15.52		-
a 34.4	Bulk Tank #2 820 " "		142.39		- 90.85	-		-15.52		-
a 34.4	Bulk Tank #3 820 " "		142.39		-100.92	-		+ 0.59	-	
a 34.4	Bult Tank #4 820 " "		142.39		- 90.85	-		+ 0.59	-	
a 34.4	Bulk Tank #5 820 " "		142.39		- 80.74	-		+ 0.59	-	
a 34.4	Bulk Tank #6 820 " "		142.39		- 70.67	-		+ 0.59	-	
a 34.4	Bulk Tank #7 820 " "		142.39		-100.92	-		+16.67	-	
a 34.4	Bulk Tank #8 820 " "		142.39		- 90.85	-		+16.67	-	
a 34.4	Bulk Tank #9 820 " "		142.39		- 80.74	-		+16.67	-	
a 34.4	Bulk Tank #10 820 " "		142.39		- 70.67	-		+16.67	-	
a 9.2	Surge Tank for Cement 220 " "		143.70		- 73.59	-		-13.65		-
b 113.0	Bulk Tank #11 1,875 " "		77.82		- 35.0	-		-98.5		-
b 113.0	Bulk Tank #12 1,875 " "		77.82		+ 35.0		-	-98.5		-
b 113.0	Bulk Tank #13 1,875 " "		77.82		- 35.0	-		+98.5	-	
b 113.0	Bulk Tank #14 1,875 " "		77.82		+ 35.0		-	+98.5	-	
b 116.0	Bulk Tank #15 1,925 " "		108.63		- 35.0	-		-98.		-
b 116.0	Bulk Tank #16 1,925 " "		108.63		+ 35.0		-	-98.		-
b 116.0	Bulk Tank #17 1,925 " "		108.63		- 35.0	-		+98.	-	
191.0	Sack Storage Fwd Outbd		142.		- 97.4	-		-81.0		-
	" " " "					-				-
202.7	" " Fwd Inbd		142.		- 97.4	-		-41.2		-
	" " " "					-				-
202.7	" " Aft Inbd		142.		- 55.2	-		-41.2		-
	" " " "					-				-

a. Cement at 94 lb/cu. ft.
b. Barite at 135 lb/cu.ft.

LOADING TABLE 2B DECK SOLID LOADS

MAX. WEIGHT L. TONS	ITEM	ACTUAL WEIGHT L. TONS	VCG FT.	VERTICAL MOMENT LT X FT	LCG FT.	LONG. MOMENT L.T. X FT.		TCG FT.	TRANS. MOMENT L.T. X FT.	
						+AFT	-FWD		-PORT	+STBD
	Pipe Rack Aft Port		15 .		+77.0		-	- .		-
888.0							-			-
										-
888.0	Pipe Rack Aft Stbd		155.0		+77.0		-	+ .	-	
							-		-	
892.0	Pipe Rack Ft @ 5" D. Pipe (21#/ft w.TJ)					-				-
	@ 6" Drill Collars					-				-
	@ 8" Drill Collars					-				-
267.0	Set Back		220.3		0	-		+ 8.7	-	
280.0	Rack Area								•	
	Midship Port									
7.0	Exploration Logging Unit		154.5		+38.0		-	-47.		-
20.0	Store at Mud Return Pit Flat, Shackles, etc		150.0		+19.0			-41.		-
85.0	Diving Equipment		140.0		+19.0		-	+50.	-	
285.7	Riser Tensioner Load (Max 8 @ 80,000#)		169.0		0	-	-	0	-	-
42.9	Guideline Tensioner Load (Max 6 @ 16,000#)		169.0		0	-	-	0	-	-
89.3	18 3/4" Blowout Preventer VETCO 10,000#		140.0		0	-	-	+39.5	-	
20.0	21" Lower Riser Package		138.5		0	-	-	+53.0	-	
9.0	Permanent and Temporary Guide		133.0		0	-	-	+24.0	-	
	Stores Containers (Empty)									
66.0	Drilling Equipment Stores									
120.0	Lower Deck Midship Stbd Store		140.0		0			+82.0	-	
30.0	Lower Deck Fwd. Box Girder Stores		138.0		-35			+20.0	-	
50.0	Lower Deck Aft (Mech., Elec., Spares, Stores)		138.0		+70			+50.0	-	
25.0	Crew, Effects, Provisions		150.0		-55.0	-		+50.0	-	

LOADING TABLE 3- DECK LOADS (LIQUID)

MAX. WEIGHT L. TONS	MAX F.S. MOM. L. TONS X FT.		TANK	ACTUAL WEIGHT L. TONS	VCG FT.	VERT. MOMENT L.T. FT.	LCG FT.	LONGL. MOMENT L. TONS X FT.		TCG FT.	TRANS MOMENT L. TONS X FT		FREE SURF MOM L. TONS X FT	
	LONGL	TRANS						+AFT	-FWD		-PORT	+STBD	LONGL	TRANS
12.2	24	52	Fuel Oil Overflow				+ 35.00		-	+ 62.55	-			
83.4	29	99	Fuel Oil Sett.				+ 35.00		-	+ 46.73	-			
76.1	27	75	Fuel Oil Day Tk. #1				+ 35.00		-	+ 30.00	-			
3.3	4	-	Fuel Oil Day Tk. #2				+ 61.94		-	+ 57.09	-			-
6.7	9	3	Steam Gen. F.O. Tk.				+ 35.00		-	- 59.12		-		
3.2	3	1	Em. Gen. F.O. Tk.				+ 92.52		-	+ 98.36	-			
18.8	36	189	Helicopter F.O. Tk.				- 35.00	-		+ 80.50	-			
16.0	12	5	Lub Oil Storage				+ 35.00		-	+ 58.73	-			
112.0	38	161	Salt Water Tk.				+ 35.00		-	- 71.73		-		
103.9	37	139	Drill Water Tk.				+ 35.00		-	- 90.75		-		
179.7	63	717	Potable Water Tk.				+ 35.00		-	- 38.00		-		
1.9	-	4	Draw Wks Cool Tk.				- 28.90	-		- 33.99		-	-	
1.9	-	-	W/W Cool Tk #1		136.19		+111.94		-	- 75.39		-	-	-
1.9	-	-	W/W Cool Tk #2		136.19		+111.94		-	+ 75.39	-		-	-
1.9	-	-	W/W Cool Tk #3		135.63		-114.31	-		- 87.76		-	-	-
1.9	-	-	W/W Cool Tk #4		136.94		-115.78	-		+108.34	-		-	-
105.6	172	305	Mud Pit #1				- 18.61	-		- 90.76		-		
106.0	174	306	Mud Pit #2				- 4.67	-		- 90.76		-		
106.2	175	306	Mud Pit #3				+ 9.32		-	- 90.76		-		
105.4	171	304	Mud Pit #4				+ 23.27		-	- 90.76		-		
35.3	6	102	Slugging Pit				- 27.90	-		- 90.76		-		
20.7	13	13	Mud Return Pit #1		148.66		+ 14.76		-	- 33.99		-		
20.7	13	13	Mud Return Pit #2		148.66		+ 6.76		-	- 33.99		-		
20.7	13	13	Mud Return Pit #3		148.66		- 1.25	-		- 33.99		-		
20.7	13	13	Mud Return Pit #4		148.66		- 9.25	-		- 33.99		-		
20.7	13	13	Mud Return Pit #5		148.66		- 17.26	-		- 33.99		-		

LOADING TABLE 4 - LOWER HULLS (FUEL, DRILL WATER & COOLING WATER)

MAX WEIGHT	MAX. F.S. MOM. L. TONS X FT.		TANK	ACTUAL WEIGHT	VCG	VERT. MOMENT	LCG	LONGL. MOMENT L. TONS X FT.		TCG	TRANS MOMENT L. TONS X FT.		FREE SURF MOM L. TONS X FT.	
L. TONS	LONGL.	TRANS		L. TONS	FT.	L.T.FT.	FT.	+AFT	-FWD	FT.	-PORT	+STBD	LONGL.	TRANS.
797.9	3903	2598	PT 5 Drill Water				-	-		-		-		
797.9	3903	2598	ST 5 Drill Water				-	-		+	-			
787.2	4553	2734	PT 13 Drill Water				+		-	-		-		
787.2	4553	2734	ST 13 Drill Water				+		-	+	-			
667.6	3862	2319	PT 6 Fuel				-	-		-		-		
667.6	3862	2319	ST 6 Fuel				-	-		+	-			
667.6	3862	2319	PT 12 Fuel				+		-	-		-		
667.6	3862	2319	ST 12 Fuel				+		-	+	-			
41.6	64	71	Port Stern Tube Cooling Water	41.6	10.54	438	+192.47	8,007	-	-100.00		-	-	-
41.6	64	71	Stbd Stern Tube Cooling Water	41.6	10.54	438	+192.47	8,007	-	+100.00	-		-	-

LOADING TABLE 5 - LOWER HULLS (BALLAST)

MAX WEIGHT	MAX F.S. MOM. L. TONS FT.		TANK	ACTUAL WEIGHT	VCG	VERT. MOMENT	LCG	LONGL. MOMENT L. TONS FT.		TCG	TRANS MOMENT L. TONS FT.		FREE SURF MOM L. TONS FT.	
L. TONS	LONGL.	TRANS		L. TONS	FT.	L.T.FT.	FT.	+AFT	-FWD	FT.	-PORT	+STBD	LONGL.	TRANS.
512.2	755	684	PT 1	.	.		.	-		.		-		
512.2	755	684	ST 1	.	.		.	-		.	-			
959.9	7680	2979	PT 2	.	.		.	-		.		-		
959.9	7680	2979	ST 2	.	.		.	-		.	-			
959.9	7680	2979	PT 3	.	.		.	-		.		-		
959.9	7680	2979	ST 3	.	.		.	-		.	-			
816.6	4001	2663	PT 4	.	.		.	-		.		-		
816.6	4001	2663	ST 4	.	.		.	-		.	-			
807.0	4667	2803	PT 7	.	.		.	-		.		-		
807.0	4667	2803	ST 7	.	.		.	-		.	-			
710.6	3127	2453	PT 8	.	.		.	-		.		-		
710.6	3127	2453	ST 8	.	.		.	-		.	-			
710.7	3127	2453	PT 9	.	.		.	-		.		-		
710.7	3127	2453	ST 9	.	.		.	-		.	-			
710.6	3127	2453	PT 10	.	.		.		-	.		-		
710.6	3127	2453	ST 10	.	.		.		-	.	-			
710.7	3127	2453	PT 11	.	.		.		-	.		-		
710.7	3127	2453	ST 11	.	.		.		-	.	-			
816.6	4001	2663	PT 14	.	.		.		-	.		-		
816.6	4001	2663	ST 14	.	.		.		-	.	-			
817.9	4001	2663	PT 15	.	.		.		-	.		-		
817.9	4001	2663	ST 15	.	.		.		-	.	-			
347.5	1740	569	PT 16	.	.		132.33		-	.		-		
347.5	1740	569	ST 16	.	.		132.33		-	.	-			
				.	.		.							

CONDITION

SUMMARY TABLE 6

ITEMS	WEIGHT LONG TONS	VCG FT.	VERTICAL MOMENT TONS X FT	LCG FT.	LONGL. MOMENT TONS X FT.		TCG FT.	TRANS. MOMENT TONS X FT.		FREE SURFACE M. TONS X FT.	
					+AFT	-FWD		-PORT	+STBD	LONGL.	TRANS.
CONDITION AT DRAFT											

L.C.B.

Operational Lightweight											
Bulk & Sack Storage Table 2A											
Deck Loads (Solid) Table 2B											
Deck Loads (Liquid) Table 3											
Lower Hull (Fuel & D.W.) Table 4											
Total (Excluding Ballast)											
Required Ballast Table 5											
Total Displacement											

VCG

45° Diag. F.S.,Mom.

LONGITUDINAL STABILITY

VCG Vertical Centre of Gravity	. FT
Free Surface Correction $\frac{\text{F.S. Longl.}}{\text{Displacement}}$	. FT
KG_L Vertical Centre of Gravity (Corrected) By Addition	. FT

At Ft. Mean Draft KG_L must not exceed . FT

KM_L Longitudinal Metacentre above Base	. FT
KG_L Vertical Centre of Gravity - After Correction	. FT
GM_L Longitudinal Metacentric Height (Corrected)	. FT

45° DIAGONAL STABILITY

VCG Vertical Centre of Gravity	. FT
Free Surface Correction $\frac{\text{F.S. Diag.}}{\text{Displacement}}$	. FT
KG_D Vertical Centre of Gravity (Corrected) By Addition	. FT

At Ft. Mean Draft KG_D must not exceed . FT

KM_D Diagonal Metacentre above Base	. FT
KG_D Vertical Centre of Gravity - After Correction	. FT
GM_D Diagonal Metacentric Height (Corrected)	. FT

CONDITION TRANSIT

SUMMARY TABLE 6 A

ITEMS	WEIGHT LONG TONS	VCG FT.	VERTICAL MOMENT TONS X FT	LCG FT.	LONGL. MOMENT TONS X FT.		TCG FT.	TRANS. MOMENT TONS X FT.		FREE SURFACE M. TONS X FT.	
					+AFT	-FWD		-PORT	+STBD	LONGL.	TRANS.
CONDITION AT DRAFT											

L.C.B

Operational Lightweight											
Bulk & Sack Storage Table 2A											
Deck Loads (Solid) Table 2B											
Deck Loads (Liquid) Table 3											
Ballast Table 5											
Total (EXCL. L. HULL FUEL & DRILL WATER)											
Lower Hull (Fuel & D.W.) Table 4											
Total Displacement											

VCG

LONGITUDINAL STABILITY

VCG (UNCORRECTED)	. FT
FREE SURFACE CORR'N $\frac{\text{L.S. LONG'L MOM.}}{\text{DISPLACEMENT}}$	. FT
VCG (CORRECTED) KG_L By Addition	. FT
KG_L At Ft. Mean Draft must not exceed Ft.	
KM_L Long'l Metacentre above ℄	. FT
KG_L As Corrected	. FT
GM_L Long'l Corr'd Metacentric Ht	. FT

Trim in degrees $\frac{(\quad)}{\quad} \times 57.3 =$

Trim - see page C-8

Trim in feet between marks

$= \frac{(1) \times (2)}{(3)}$

$= \frac{\quad \times \quad}{\quad} =$ ft. down

Forward Marks from ⊕ =

Aft Marks from ⊕ =

Draft at Drum of Fwd. Marks

= Equiv level draft ± trim x [illegible]

= ( ) = ft.

Draft at Drum of Aft Marks

= Equiv level draft ± Trim x [illegible]

= ( ) = ft.

TRANSVERSE STABILITY

VCG (UNCORRECTED)	. FT
FREE SURFACE CORR'N $\frac{\text{F.S. TRANS. MOM.}}{\text{DISPLACEMENT}}$	. FT
VCG (CORRECTED) KG_T By Addition	. FT
KG_T At Ft. Mean Draft must not exceed Ft.	
KM_T Trans. Metacentre above ℄	. FT
KG_T As Corrected	. FT
GM_T Trans. Corr'd Metacentric Ht	. FT

List - see C-8 - 'List at Draft'

$\text{List} = \frac{(4) \times (5)}{(6)}$

$= \frac{\quad}{\quad}$

Draft at Port Marks

= Equiv. level draft ± list/2.

=

Draft at Stbd Marks

= Equiv. level draft ± list/2.

=

WEATHER DATA

APPENDIX E

APPENDIX E

WEATHER DATA

1. TELEX REGARDING DEFINITION OF PARAMETERS IN SITE-SPECIFIC FORECASTS 239
NORDCO Limited to Mobil Oil Canada Limited
September 1, 1982.
Exhibit #115.

2. SITE SPECIFIC WEATHER FORECASTS 240
February 13 to 15, 1982 issued by NORDCO Limited to Mobil Oil Canada Limited.
Extract from Exhibit #60.

3. GUIDE TO MARINE FORECASTS, NORDCO LIMITED 246
January 1, 1980.

4. DESCRIPTION OF FEBRUARY 14-15, 1982 STORM 247
Extracted from section 5.7 of "The Analysis of Weather Conditions experienced by the *Ocean Ranger*, November 1980 to February 15, 1982"
Atmospheric Environment Services, Bedford, Nova Scotia.

5. WAVE DATA FROM THE *ZAPATA UGLAND* 257
Station 140, February 14 to 16, 1982.
Exhibit #119.

6. WEATHER OBSERVATIONS FOR FEBRUARY 14-15, 1982 258
From the *Zapata Ugland*, *SEDCO 706* and *Ocean Ranger*
Extract from Exhibit #117.

Item E-1
Telex Regarding Definition of Parameters in Site-Specific Forecasts

MOBIL HO SNF '82 SEP -1 13:24

NORDCO SNF
SEPT 1 1982

MESSAGE NO 9026

MOBIL OIL CANADA
ST. JOHN'S

ATTN M. HASSEL

SUBJ: DEFINITION OF PARAMETERS IN SITE-SPECIFIC FORECASTS 173-81

1. DEFINITIONS GIVEN BELOW IN RESPONSE TO OUR TELECON THIS AM DO NOT HESITATE TO CONTACT ME IF I CAN BE OF FURTHER SERVICE.
2. WIND AT ANEMOMETER

DIRECTION AND SPEED: THE EXPECTED AVERAGE SPEED AND DIRECTION OF THE THREE ONE-MINUTE MEANS THAT WILL BE OBSERVED ON THE RIG ANEMOMETER, WHEN SHE IS AT OPERATING DRAFT AT THE VALID TIME T AND AT T - 3 AND T + 3 HOURS. THE ONE-MINUTE MEANS ARE THOSE THAT WILL BE RECORDED BY THE OBSERVER AND TRANSMITTED IN THE THREE HOURLY MAPMAR OBSERVATION.

MAXIMUM SPEED: THE HIGHEST SINGLE WIND GUST ANTICIPATED AT THE RIG ANEMOMETER BETWEEN T - 3 AND T + 3 HOURS.

3. SEA WAVE

SIG HEIGHT: THE EXPECTED AVERAGE HEIGHT OF THE HIGHEST ONE-THIRD OF THE WAVES GENERATED BY THE WIND BLOWING AT THE SEA SURFACE IN THE VICINITY OF THE RIG AT THE VALID TIME.

MAX HEIGHT: AS FOR SIG HEIGHT, BUT THE AVERAGE HEIGHT OF THE HIGHEST ONE-HUNDRETH OF THE WAVES.

PERIOD: AVERAGE ZERO-CROSSING PERIOD OF THE WIND GENERATED WAVES.

4. SWELL WAVE:

DIRECTION: THE DIRECTION FROM WHICH THE PREDOMINANT SWELL TRAIN WILL ARRIVE

HEIGHT: THE EXPECTED AVERAGE HEIGHT OF THE HIGHEST ONE THIRD OF THE WAVES IN THE SWELL TRAIN.

PERIOD: THE AVERAGE ZERO-CROSSING PERIOD OF THE WAVES IN THE SWELL TRAIN

5. COMBINED SEA:

SIG HEIGHT: SQRT ((SIG WAVE HEIGHT) **2 + (SWELL HEIGHT) **2)

USING THE ABOVE DEFINITIONS

MAX HEIGHT: SQRT ((MAX WAVE HEIGHT) **2 + (MAX SWELL HEIGHT) **2)

WHERE MAX WAVE HEIGHT IS AS DEFINED ABOVE AND MAX SWELL HEIGHT IS THE AVERAGE HEIGHT OF THE HIGHEST ONE-HUNDREDTH OF THE WAVES IN THE SWELL TRAIN

SQRT (X) MEANS SQUARE ROOT OF X
X**N MEANS X RAISED TO POWER OF N

I WILL DELIVER TYPED COPY OF ABOVE SOONEST FOR CONFIRMATION

REGARDS

M. HEWSON
MOBIL HO SNF

NORDCO SNF

Item E-2
Site Specific Weather Forecasts for February 13-15, 1982

4095
MOBIL RDO SNF
NORDCO WX SNF
TIME OF ISSUE 13/0500Z

FORECAST FOR THE OCEAN RANGER, SEDCO 706, AND ZAPATA UGLAND ISSUED BY NORDCO LIMITED FOR MOBIL OIL CANADA AT 0130 NST SATURDAY, FEB 13, 1982 VALID UNTIL 2030 NST SUNDAY WITH AN OUTLOOK FOR THE NEXT THPEE DAYS.

WARNINGS IN EFFECT. . . .GALE UPGRADED TO STORM, FREEZING SPRAY CONTINUE

VALID TIME	13/12Z	13/18Z	14/00Z	14/06Z	14/12Z	14/18Z	15/00Z
NST	0830	1430	2030	0230	0830	1430	2030
WIND							
DIRECTION	300	280	VRBL	140	110	150	360
SPEED	35	25	10	20	35	50	45
MAX SPEED	45	30	15	30	45	60	55
SEA WAVE							
SIG HEIGHT	10	7	2	5	8	14	8
MAX HEIGHT	17	12	3	9	14	24	14
PERIOD	7	6	3	5	6	8	6
SWELL WAVE							
DIRECTION	NIL	330	280	270	140	140	180
HEIGHT		5	4	4	5	6	10
PERIOD		8	8	9	8	9	10
SKY	BKN/OVC		BKN/SCT	OVC	OVC	OVC/OBSCD	
AIR TEMP.	−5	−4	−2	−1	0	+3	+2
VSBY	6+ OCNL	5	6+	6+	4	1-2 OCNL	1/4
WEATHER	FEW SW−		NIL	NIL	MIST	RW.F	

OUTLOOK VALID 00Z MONDAY TO 24Z WEDNESDAY

MONDAY WIND NW 40-50 VSBY POOR/GOOD MCS 22 FT
TUESDAY WIND NW BCMG W 20 VSBY GOOD MCS 18 FT
WEDNESDAY WIND SW 30 BCMG NW 35 VSBY FAIR/GOOD MCS 14 FT

SYNOPSIS:

NORTHWEST GALE THIS MORNING IS FORECAST TO DEMINISH TO STRONG THIS AFTERNOON AND LIGHT THIS EVENING AS A HIGH PRESSURE CENTER AREA APPROACHES THE MOBIL DRILLING AREA.

ON SUNDAY, A DEEP LOW CENTER IS FORECAST TO MOVE INTO THE AREA. AS A RESULT, STORM WARNING IS IN EFFECT. THE LOW IS CURRENTLY SOUTH OF CAPE HATTERAS.

THE NEXT REGULAR FORECAST WILL BE ISSUED AT 13/1100Z

WIND SPEED IN KNOTS, WAVE HEIGHTS IN FEET, PERIODS IN SECONDS, ALL DIRECTIONS IN DEGREES TRUE, VISIBILITY IN NAUTICAL MILES, TEMPERATURES IN CELSIUS

END

MOBIL RDO SNF

NORDCO WX SNF

3216

TIME OF ISSUE 13/1100Z

FORECAST FOR THE OCEAN RANGER, SEDCO 706, AND ZAPATA UGLAND ISSUED BY NORDCO LIMITED FOR MOBIL OIL CANADA AT 0730 NST SATURDAY, FEB 13, 1982 VALID UNTIL 2030 NST SUNDAY WITH AN OUTLOOK FOR THE NEXT THREE DAYS

WARNINGS IN EFFECT . . . '594 . FREEZING SPRAY CONTINUE

VALID TIME	13/12Z	13/18Z	14/00Z	14/06Z	14/12Z	14/18Z	15/00Z
NST	0830	1430	2030	0230	0830	1430	2030
WIND							
DIRECTION	300	280	VRBL	140	110	180	360
SPEED	35	25	10	30	45	50	45
MAX SPEED	45	30	15	40	55	60	55
SEA WAVE							
SIG HEIGHT	10	7	2	7	12	14	8
MAX HEIGHT	17	12	3	12	20	24	14
PERIOD	7	6	3	6	8	8	6
SWELL WAVE							
DIRECTION	NIL	330	280	270	140	140	180
HEIGHT		5	4	4	5	6	10
PERIOD		8	6	9	8	9	10
SKY	BKN/OVC		BKN/SCT	OVC	OVC	OVC/OBSCD	
AIR TEMP	−5	−4	−2	−1	0	+3	+2
VSBY	6+OCNL	5	6+	6+	4	1-2 OCNL	1/4
WEATHER	FEW SW−		NIL	NIL	MIST	RW F	

OUTLOOK VALID 00Z MONDAY TO 24Z WEDNESDAY

MONDAY WIND NW 40-50 VSBY POOR/GOOD MCS 25 FT
TUESDAY WIND NW 30 BCMG W 20 VSBY GOOD MCS 18 FT
WEDNESDAY WIND SW 30 BCMG NW 35 VSBY FAIR/GOOD MCS 14 FT

SYNOPSIS

NORTHWEST GALE THIS MORNING IS FORECAST TO DEMINISH TO STRONG THIS AFTERNOON AND LIGHT THIS EVENING AS A HIGH PRESSURE CENTER AREA APPROACHES THE MOBIL DRILLING AREA.

ON SUNDAY, A DEEP LOW CENTER IS FORECAST TO MOVE INTO THE AREA. AS A RESULT, STORM WARNING IS IN EFFECT. THE LOW IS CURRENTLY AROUND 200 N.MILES EAST OF CAPE HATTERAS

503 .3/5 43O7)-4 0943.-'5 28)) ?3 8''73
MOBIL RDO SNF

CORRECTION PLS READ IN WARNINGS . . . STORM WARNING. FREEZING
THE LAST LINE . . . THE NEXT REGULAR FCST WILL BE ISSUED AT 13/1700Z

MOBIL RDO SNF

NORDCO WX SNF

TIME OF ISSUE 13/2300Z

FORECAST FOR THE OCEAN RANGER, SECDO 706 AND ZAPATA UGLAND ISSUED BY NORDCO LIMITED FOR MOBIL OIL CANADA AT 1930 NST SATURDAY, FEBRUARY 13, 1982. VALID UNTIL 0830 NST MONDAY WITH AN OUTLOOK FOR THE NEXT THREE DAYS.

WARNINGS IN EFFECT. . . . STORM, WAVE AND FREEZING SPRAY. . . .

VALID TIME NST	14/00Z 2030	14/06Z 0230	14/12Z 0830	14/18Z 1430	15/00Z 2030	15/06Z 0230	15/12Z 0830
WIND AT ANENOMETER							
DIRECTION	180	140	110	230	270	320	320
SPEED	10	35	50	55	45	60	45
MAX SPEED	15	45	65	70	55	75	55
SEA WAVE							
SIG HEIGHT	2	6	11	13	17	22	28
MAX HEIGHT	3	18	19	22	29	39	35
PERIOD	4	5	8	9	9	18	9
SWELL							
DIRECTION	300	300	NIL	NIL	NIL	NIL	NIL
HEIGHT	12	7					
PERIOD	9	10					
SKY	OVC	OVC	OBSCD OCNL OVC		OVC	OVC OCNL	OBSCD
AIR TEMP	-6	-3	-1	+6	0	-3	-6
VSBY	6+	6+	1-2 OCNL 1/8		1-5	1-5 OCNL	3/8-1
WEATHER	NIL	NIL	S-/S CHNGNG TO R-/R OCNL R+ TRW AFTER 15Z MIST. FOG PTCHS		SW	SW-/ SW	SW-/ SW
	OCNL LGT FRZG SPRAY					FRZG SPRAY	

OUTLOOK VALID 12Z MONDAY TO 24Z WEDNESDAY

MON WIND NW 30-40 VSBY FAIR MCS 25 FT.
TUE WIND 25 BCMG N20 VSBY GOOD MCS 18 FT.
WED WIND SW 30 BCMG NW 35 VSBY FAIR MCS 15 FT.

SYNOPSIS:

A HIGH PRESSURE CELL CROSSING THE GRAND BANKS THIS EVENING WILL BRING LIGHT AND VARIABLE WINDS. A GALE CENTER CURRENTLY ESTIMATED AT 987 NB NEAR 39N 66W RACING NORTHEASTWARD AT 40 KNOTS IS FORECAST TO DEVELOP INTO A STORM CENTER OVERNIGHT AND PASS BETWEEN ST. JOHN'S AND THE DRILL AREA ABOUT NOON ON SUNDAY THEN CONTINUE INTO THE ATLANTIC. GALE FORCE SOUTHEAST WINDS EXPECTED TO SPREAD OVER THE DRILL AREA AROUND 14/06Z OR SHORTLY AFTERWARD THEN INCREASE TO STORM FORCE AFTER DAWN. THE ASSOCIATED WARM FRONT EXTENDING EASTWARD FROM THE CENTER IS FORECAST TO CROSS THE AREA TOWARD NOON WITH SNOW CHANGING TO RAIN AS IT DOES. A COLD FRONT TRAILING SOUTHWARD FROM THE STORM CENTER WILL SWEEP ACROSS THE AREA IN THE LATE AFTERNOON WITH GALE TO STORM FORCE WEST TO NORTHWEST WINDS, HEAVY SEAS, FLURRIES, AND FREEZING SPRAY ANTICIPATED SUNDAY NIGHT.

THE NEXT REGULAR FORECAST WILL BE ISSUED AT 14/0500Z

END

NORDCO WX SNF

NORDCO WX SNF

TIME OF ISSUE 14/0500Z

FORECAST FOR THE OCEAN RANGER, SEDCO 706 AND ZAPATA UGLAND ISSUED BY NORDCO LIMITED FOR MOBIL OIL CANADA AT 0130 NST SUNDAY, FEB 14, 1982 VALID UNTIL 2030 NST MONDAY, WITH AN OUTLOOK FOR THE NEXT THREE DAYS.

WARNINGS IN EFFECT . . . STORM , WAVE AND FREEZING SPRAY

VALID TIME NST	14/12Z 0830	14/18Z 1430	15/00Z 2030	15/06Z 0230	15/12Z 0830	15/18Z 1430	16/00Z 2030
WIND							
DIRECTION	140	230	270	300	320	310	300
SPEED	45	55	45	65	50	45	25
MAX SPEED	55	70	55	80	65	50	35
SEA WAVE							
SIG HEIGHT	6	12	14	20	25	22	14
MAX HEIGHT	10	20	24	34	43	37	24
PERIOD	5	7	8	10	11	10	8
SWELL WAVE							
DIRECTION	NIL	180	140	NIL	NIL	NIL	010
HEIGHT		6	7				10
PERIOD		7	3				10
SKY	OBSCD/OVC		OVC	OVC OCNL	OBSCD	OVC/BKN	
AIR TEMP	-1	+6	0	-3	-4	-5	-6
VSBY	1-2 OCNL	1/8	1-5	1-5 OCNL	1/2	6+ OCNL	4
WEATHER	S-F	RW.F RSK TRW	RW-/SW-	SW-F	OCNL	SW-F OCNL	SW-

OUTLOOK VALID 00Z MONDAY TO 24Z WEDNESDAY

MONDAY WIND NW 30 BCMG SE 20 VSBY GOOD MCS 25 FT
TUESDAY WIND SW 20-30 VSBY GOOD/FAIR MCS 18 FT
WEDNESDAY WIND SW -NW 20-30 VSBY GOOD MCS 15 FT

SYNOPSIS:

A 987MB STOPM CENTER WAS LOCATED NEAR 40N 65W AT 14/0000Z. THIS DEE P LOW CENTER IS RACING NORTHEAST AT 40 KNOTS AND FORECAST TO PASS BETWEEN ST. JOHN'S AND THE DRILLING AREA ABOUT 14/1800Z.

LIGHT SOUTHERLY WINDS AT 14/0300Z FROM THE MOBIL RIGS ARE FORECAST TO REACH GALE FORCE WINDS BY 14/1200Z. STORM, WAVE, AND FREEZING SPRAY WARNINGS ARE IN EFFECT.

WIND SPEED IN KNOTS, WAVE HEIGHTS IN FEET, PERIODS IN SECONDS, ALL DIRECTIONS IN DEGREES TRUE, VISIBILITY IN NAUTICAL MILES, TEMPERATURES IN CELSIUS.

END

MOBIL RDO SNF

NORDCO WX SNF

3216

3216

MOBIL DCK SNF

TIME OF ISSUE 14/1100Z

FORECAST FOR THE OCEAN RANGER, SEDCO 706 AND ZAPATA UGLAND ISSUED BY NORDCO LIMITED FOR MOBIL OIL CANADA AT 0730 NST SUNDAY, FEB 14, 1982 VALID UNTIL 2030 NST MONDAY, WITH AN OUTLOOK FOR THE NEXT THREE DAYS

WARNINGS IN EFFECT . . . STORM, WAVE AND FREEZING SPRAY

VALID TIME NST	14/12Z 0830	14/18Z 1430	15/00Z 2030	15/06Z 0230	15/12Z 0830	15/18Z 1430	16/00Z 2030
WIND							
DIRECTION	140	180	300	280	270	310	300
SPEED	50	65	45	40	35	30	25
MAX SPEED	60	90	55	50	45	40	35
SEA WAVE							
SIG HEIGHT	14	22	14	16	18	20	14
MAX HEIGHT	24	37	24	27	31	34	24
PERIOD	8	10	8	9	9	10	8
SWELL WAVE							
DIRECTION	NIL	140	180	360	300	NIL	010
HEIGHT		10	16	10	10		10
PERIOD		9	10	10	10		10
SKY	OBBCD/OVC .		OVC	OVC OCNL	OBSCD	OVC/BKN	
AIR TEMP.	-1	+6	0	-3	-4	-5	-6
VSBY	1-2 OCNL	1/8	1-5	1-5 OCNL	1/2	6+ OCNL	4
WEATHER	S-F	RW.F	RW-/SW- RBK TRW	SW-F	OCNL SW-F	OCNL SW	

OUTLOOK VALID 00Z MONDAY TO 24Z WEDNESDAY

MONDAY WIND NW 30 BCMG SE 20 VSBY GOOD MCS 25 FT
TUESDAY WIND SW 20-30 VSBY GOOD/FAIR MCS 18 FT
WEDNESDAY WIND SW -NW 20-30 VSBY GOOD MCS 15 FT

SYNOPSIS

A 960MB STORM CENTER WAS LOCATED AT 44.5N 58.8W AT 14/0900Z. IT MOVING NORTHEAST AT 40 KNOTS, FORECAST POSITIONS ARE 46N 57W AND 49.5N 53W AT 14/1200Z AND 14/1800Z RESPECTIVELY, NOTE THE FORECAST TRAJECTORY OF THE LOW CENTER HAS BEEN AMMENDED TO MORE NORTHERLY THAN THE PREVIOUS FORECAST, BUT DRASTIC DEEPENING OF THE PRESSURE CENTER WILL CREATE HIGHER WINDS AND WAVES EARLIER THAN EXPECTED IN THE PREVIOUS FORECAST.

COLD FRONT ASSOCIATED WITH THIS STORM IS FORECAST TO PASS OVER THE RIGS SHORTLY AFTER 14/1800Z.

WIND SPEED IN KNOTS, WAVE HEIGHTS IN FEET, PERIODS IN SECONDS, ALL DIRECTIONS IN DEGREES TRUE, VISIBILITY IN NAUTICAL MILES, TEMPERATURES IN CELSIUS.

END

NORDCO WX SNF

MOBIL DCK SNF

ISSUE TIME 14/1700Z

FORECAST FOR THE SEDCO 706, ZAPATA UGLAND AND THE RANGER ISSUED BY NORDCO LIMITED FOR MOBIL OIL AT 1330 NST SUNDAY, FEBRUARY 14,1982 VALID UNTIL 0830 NST TUESDAY WITH AN OUTLOOK FOR THE NEXT THREE DAYS

WARNINGS IN EFFECT
STORM, WAVE AND FREEZING SPRAY CONTINUED

VALID TIMES LCL TIMES	15/00Z 2030	15/06Z 0230	15/12Z 0830	15/18Z 1430	16/00Z 2030	16/06Z 0230	16/12Z 0830
WIND AT ANEMOMETER							
DIRECTION	280	310	340	330	330	350	330
SPEED	70	60	55	50	40	30	25
MAX SPEED	90	80	65	65	50	40	35
SEA WAVE							
SIG HEIGHT	20	23	26	23	15	10	8
MAX HEIGHT	35	40	46	40	26	17	14
PERIOD	10	10	10	10	8	7	6
SWELL WAVE							
DIRECTION	NIL	NIL	NIL	330	310	300	300
HEIGHT				16	20	20	15
PERIOD				9	10	9	9
SKY COVER	OVC VRBL OBSCD			OVC	OVC/BKN		BKN
AIR TEMPERATURE	0	-3	-3	-5	-7	-8	-9
VSBY	1-5 VRBL 1/8-1/2		4-6		6 OCNL 3-5		6+
WEATHER	SW-/SW		SW- OCNL SW		OCNL SW		NIL
	LIGHT TO MODERATE OCCASIONALLY HEAVY FREEZING SPRAY						

OUTLOOK VALID 12Z TUESDAY TO 24Z THURSDAY

TUE WIND NW 25 BECOMING SE 20, VSBY GOOD, MAXIMUM COMBINED WAVE 15
WED WIND SW 20-30 , VSBY FAIR , MAXIMUM COMBINED WAVE 15
THU WIND SW-NW 20-30 VSBY GOOD , MAXIMUM COMBINED SEA 13

SYNOPSIS

960 MB STORM CENTER SOUTH OF AVALON PENINSULA AT 1200Z WILL MOVE NORTHEASTWARD RAPIDLY.

STORM FORCE NORTHWESTERLIES AND POOR VISIBILITIES AND ROUGH SEAS ARE EXPECTED TO PERSIST TONIGHT, DIMINISHING TO GALE FORCE WINDS AND IMPROVING VISIBILITIES TO FAIR DECREASING WAVE HEIGHTS BY MONDAY NOON.

WEATHER CONDITIONS WILL IMPROVE SUBSTANTIALLY WITH A RIDGE THAT WILL APPROACH THE DRILLING AREA BY MONDAY NIGHT OR EARLY TUESDAY MORNING.

THE NEXT REGULAR FORECAST WILL BE ISSUED AT 14/2300Z

WIND SPEED IN KNOTS, WAVE HEIGHTS IN FEET, PERIODS IN SECONDS, ALL DIRECTIONS IN DEGREES TRUE, VISIBILITY IN NAUTICAL MILES, TEMERATURES IN CELSIUS.

END

MOBIL RDO SNF

NORDCO WX SNF

4895

MOBIL RDO SNF
NORDCO WX SNF

ISSUE TIME 14/2300Z

FORECAST FOR THE SEDCO 706, ZAPATA UGLAND AND THE RANGER ISSUED BY NORDCO LIMITED FOR MOBIL OIL CANADA AT 1930 NST SUNDAY, FEBRUARY 14, 1982 VALID UNTIL 0830 NST TUESDAY WITH AN OUTLOOK FOR THE NEXT THREE DAYS.

WARNINGS IN EFFECT STORM, WAVE AND FREEZING SPRAY CONTINUED

VALID TIMES	15/00Z	15/06Z	15/12Z	15/18Z	16/00Z	16/06Z	16/12Z
LCL TIMES	2030	0230	0830	1430	2030	0230	0830
WIND AT ANEMOMETER							
DIRECTION	270	330	330	330	310	260	200
SPEED	75	70	60	50	40	25	35
MAXSPEED	90	80	75	60	50	35	45
SEA WAVE							
SIG HEIGHT	25	33	30	20	15	6	10
MAX HEIGHT	44	59	54	35	25	10	17
PERIOD	9	10	10	9	8	6	7
SWELL WAVE							
DIRECTION	320	NIL	NIL	NIL	NIL	330	310
HEIGHT	15					16	16
PERIOD	9					9	8
SKY	OBSCD		OVC	OVC	BKN	SCT	BKN/ OVC
AIR TEMP	– 2	– 5	– 9	– 6	– 3	+ 1	+ 5
VSBY	2-4 VRBL 1/8-1		6 OCNL 2-4 .		6	6	2-4
WEATHER	SW-/SW		OCNL SW –		NIL	NIL	MIST/ R-
FREEZING SPRAY	MODERATE TO HEAVY		LIGHT TO MODERATE			NIL	NIL

OUTLOOK VALID 12Z TUESDAY TO 24Z THURSDAY

TUE WIND SE 30-40 VSBY POOR MCS 16 FT.
WED WIND NW 30-40 VSBY FAIR MCS 20 FT.
THU WIND NE 20-30 VSBY POOR MCS 13 FT.

SYNOPSIS:

A COLD FRONT FROM A STORM CENTER, EAST OF THE AVALON PENINSULA ABOUT 2000Z, EXTENDING SOUTHWARD ALONG 50 W WILL LIE OVER THE RIGS BETWEEN 0100-0300Z. STORM FORCE NORTHWESTERLIES, POOR VISIBILITIES AND ROUGH SEAS WILL PERSIST TONIGHT

A RIDGE OF HIGH PRESSURE OVER QUEBEC WILL MOVE TO THE DRILLING AREA MONDAY NIGHT, MAINTAINING STRONG SOUTHWESTERLIES, GOOD VISIBILITIES AND SEAS 10-15 FEET MOSTLY FROM NORTHWESTERLY SWELLS.

A WARM TROUGH FROM A DEEPENING LOW MOVING TO SOUTHERN LABRADOR WILL EXTEND ALONG WESTERN NEWFOUNDLAND. THIS SYSTEM WILL BRING SOUTHWESTERLY GALES AND BY TUESDAY MORNING, FAIR TO POOR VISIBILITIES IN FOG AND RAIN/RAINSHOWERS AND INCREASING TEMPERATURES ARE EXPECTED ON TUESDAY.

WIND SPEED IN KNOTS, WAVE HEIGHTS IN FEET, PERIODS IN SECONDS, ALL DIRECTIONS IN DEGREES TRUE, VISIBILITY IN NAUTICAL MILES, TEMPERATURES IN CELSIUS.

END

MOBIL RDO SNF

MOBIL RDO SNF

NORDCO WX SNF

TIME OF ISSUE 15/0500Z

FORECAST FOR THE OCEAN RANGER, SEDCO 706, AND ZAPATA UGLAND ISSUED BY NORDCO LIMITED FOR MOBIL OIL CANADA AT 0130 NST MONDAY, FEB 15, 1982 VALID UNTIL 2030 NST TUESDAY WITH AN OUTLOOK FOR THE NEXT THREE DAYS.

WARNINGS IN EFFECT. . .STORM, WAVE, AND FREEZING SPRAY

VALID TIME	15/12Z	15/18Z	16/00Z	16/06Z	16/12Z	16/18Z	17/00Z
NST	0830	1430	2030	0230	0830	1430	2030
WIND							
DIRECTION	300	290	280	260	200	150	220
SPEED	58	45	40	25	28	35	35
MAX SPEED	75	55	50	35	38	45	45
SEA WAVE							
SIG HEIGHT	30	20	15	5	6	8	11
MAX HEIGHT	54	34	26	9	5	12	19
PERIOD	10	10	9	5	5	6	7
SWELL WAVE							
DIRECTION	NIL	NIL	NIL	310	310	NIL	NIL
HEIGHT				12	8		
PERIOD				9	9		
SKY	OVC	BKN VRBL OVC	BKN OCNL OVC		OVC	OVC OCNL	OBSCD
AIR TEMP.	– 8	– 7	– 6	– 6	– 4	– 2	– 2
VSBY	6 OCNL	1-4	6+	6+	6	1-5 OCNL	3/8-1
WEATHER	OCNL SW –		FEW SW –		NIL	S-OCNL S	
FREEZING SPRAY	MODERATE TO HEAVY					LGT TO MDT	

OUTLOOK VALID 0000Z WEDNESDAY TO 2400Z FRIDAY

WEDNESDAY WIND NW 30-45 VSBY FAIR/GOOD MCS 20 FT
THURSDAY WIND NW TO NE 20-30 VSBY GOOD/FAIR MCS 15 FT
FRIDAY WIND NW 30-40 VSBY FAIR/GOOD MCS 20 FT

SYNOPSIS:

A MAJOR WINTER STORM CURRENTLY ESTIMATED AT 953MB NEAR 50N 49W IS FORECAST TO CONTINUE NORTHEASTWARD TOWARD GREENLAND WATERS. STORM FORCE WINDS EXTEND ABOUT 400 MILES FROM THE CENTER AND GALE FORCE WINDS ABOUT 600 MILES. STORM FORCE WINDS GRADUALLY DECREASING TO GALE FORCE THIS EVENING AT THE DRILL SITES. VERY HEAVY SEAS LOWERING SLOWLY THIS AFTERNOON. FREEZING SPRAY CONTINUING THRU THE PERIOD. A RIDGE WILL CROSS THE GRAND BANKS TUESDAY MORNING. A TROUGH OF LOW PRESSURE FOLLOWING BEHIND THE RIDGE WILL REACH THE DRILL AREA TUESDAY EVENING.

WIND SPEED IN KNOTS, WAVE HEIGHTS IN FEET, PERIODS IN SECONDS, ALL DIRECTIONS IN DEGREES TRUE, VISIBILITY IN NAUTICAL MILES, TEMPERATURES IN CELSIUS.

END

MOBIL RDO SNF

NORDCO WX SNF

TIME OF ISSUE 15/0730Z

UPDATE FORECAST FOR THE MOBIL DRILLING AREA ISSUED BY NORDCO LTD. FOR MOBIL OIL CANADA AT 0400 NST MONDAY, FEBRUARY 15, 1982 VALID UNTIL 1430 NST TODAY.

WARNINGS IN EFFECT. . . .STORM, WAVE AND FREEZING SPRAY CONTINUED. .

VALID TIME	15/09Z	15/12Z	15/15Z	15/18Z
LCL TIME	0530	0830	1130	1430
WIND AT ANEMOMETER				
DIRECTION	310	320	310	290
SPEED	60	58	53	45
MAX SPEED	75	70	63	55
SEA WAVE				
SIG HEIGHT	30	30	23	20
MAX HEIGHT	54	50	42	35
PERIOD	11	11	10	10
SWELL WAVE	NIL EXPECTED			
SKY	OBSCD	OVC	BKN OCNL	OVC
VSBY	1/2-2	6 OCNL 1-4		6 OCNL 3-5
WEATHER	S – /SW – OCNL SW	OCNL SW –		FEW SW –
FREEZING SPRAY	MODERATE TO HEAVY FREEZING SPRAY			
AIR TEMP	– 6	– 8	– 10	– 8

THE NEXT REGULAR FORECAST WILL BE ISSUED AT 15/1100Z

END

MOBIL RDO SNF

NORDCO SNF

SEDCO706 SNF

NORDCO WX SNF

ISSUE TIME 15/1030Z

FORECAST FOR THE SEDCO 706, ZAPATA UGLAND AND OCEAN RANGER ISSUED BY NORDCO LTD. FOR MOBIL OIL CANADA AT 0700 NST MONDAY, FEBRUARY 15, 1982 VALID UNTIL 0830 TUESDAY WITH AN OUTLOOK FOR THE NEXT THREE DAYS

WARNINGS IN EFFECT. . . .STORM WAVE AND FREEZING SPRAY WARNINGS CONTINUED. . .

VALID TIME	15/12Z	15/15Z	15/18Z	15/21Z	16/00Z	16/06Z	16/12Z	16/18Z	17/00Z
NST	0830	1130	1430	1730	2030	0230	0830	1430	2030
WIND									
DIRECTION	290	300	300	300	300	260	210	150	240
SPEED	50	50	48	48	45	25	30	35	35
MAX SPEED	65	65	60	60	55	35	40	45	45
SEA WAVE									
SIG HT	26	28	25	25	23	5	7	8	11
MAX HT	45	48	43	43	39	9	12	12	19
PERIOD	12	12	11	11	11	5	5	6	7
SWELL WAVE									
DIRECTION	NIL	NIL	NIL	NIL	NIL	310	310	310	NIL
HEIGHT						19	16	9	
PERIOD						11	11	10	
SKY	OVC				BKN				OVC OCNL OBSCD
AIR TEMP	– 7	– 8	– 7	– 6	– 6	– 4	– 2	– 1	+2
VSBY	1-4		6 OCNL 2-5			6+	6	1-5 OCNL 3/8-1	
WEATHER	SW –		OCNL SW –			FEW SW –	NIL	S – OCNL S	
FRZG SPRAY	MODERATE TO HEAVY						LGT TO MDT		

OUTLOOK VALID 00Z WEDNESDAY TO 24Z FRIDAY
WEDNESDAY WIND NW 30-45 VSBY FAIR/GOOD MCS 20 FT
THURSDAY WIND NW TO NE 20-30 VSBY GOOD/FAIR MCS 15 FT
FRIDAY WIND NW 30-40 VSBY, FAIR/GOOD MCS 20 FT

SYNOPSIS:

INTENSE WINTER STORM CURRENTLY ESTIMATED AT 953 MB NEAR 50.5N 45.0W IS EXPECTED TO MOVE GENERALLY NORTHEASTWARD AWAY FROM THE DRILL AREA TODAY. AS A CONSEQUENCE, STORM FORCE WESTERLY WINDS REPORTED FROM THE RIGS SHORTLY BEFORE FORECAST TIME THIS MORNING WILL DECREASE SLOWLY THRU THE DAY. HEAVY SEA LOWERING ONLY VERY SLOWLY TODAY. COLD TEMPERATURES CONBINED WITH THE WINDS WILL GIVE MODERATE TO HEAVY FREEZING SPRAY. VISIBILITY FAIR IN SNOW OR SNOW FLURRIES IMPROVING TO GENERALLY GOOD THIS AFTERNOON.

THE NEXT FORECAST WILL BE ISSUED AT 15/1330Z

WIND SPEED IN KNOTS, WAVE HEIGHTS IN FEET, PERIODS IN SECONDS, ALL DIRECTIONS IN DEGREES TRUE, VISIBILITY IN NAUTICAL MILES, TEMPERATURES IN CELSIUS

END

SEDCO706 SNF

NORDCO WX SNF

4684
SEDCO 706 SNF
NORDCO NX SNF
ISSUE TIME 15/1330 Z

UPDATE FORECAST FOR THE OCEAN RANGER, SEDCO 706 AND ZAPATA UGLAND ISSUED BY NORDCO LIMITED, ST. JOHN'S AT 0930 NST:MONDAY FEB. 15, 1982

SRORM WAVE AND FREEZING SPRAY WARNINGS CONTINUED

REASON FOR UPDATE

1200Z SATELLITE PHOTO SHOWS STORM CENTER NEAR 50.8N 43.9W AND MOVING EAST-NORTHEAST AT ABOUT 17 KNOTS. EXTENSIVE CLOUD BAND FROM THE CENTER OF THE LOW EXTENDS WEST TO NEWFOUNDLAND EAST COAST AND ALONG AVALON PENINSULA WITH NO BREAKS OBSERVED. LITTLE CHANGE FROM PREVIOUS FORECAST OF 1030Z EXPECTED AT THIS HOUR.

VALID TIME	15/15Z	15/18Z	15/21Z	16/00Z
WIND				
DIRECTION	300	300	300	300
SPEED	50	46	44	42
MAX SPEED	65	60	55	55
SEA WAVE				
SIG HEIGHT	28	27	26	24
MAX HEIGHT	50	49	47	43
PERIOD	12	12	12	12
SKY	OVC VRBL OBSCD			
AIR TEMP	-7	-7	-8	-8
VSBY	½ VRBL	3		
WEATHER	S - /S FOG CHNG SW - /SW			

HEAVY FREEZING SPRAY THRUT

THE NEXT REGULAR FORECAST WILL BE ISSUED AT 15/1700Z

END
SEDCO 706 SNF

NORDCO NX SNF

MOBIL RDO SNF

NORDCO NX SNF

PLEASE ADD TO UPDATE FORECAST ISSUED AT 15/1330Z

VALID TIME	15/15Z	15/18Z	15/21Z	16/00Z
SEA WAVE				
SIG HEIGHT	28	27	26	24
MAX HEIGHT	50	49	47	43
PERIOD	12	12	12	12

END
NORDCO NX SNF

Item E-3
Guide to Marine Forecasts
NORDCO Limited

January 1, 1980

GENERAL

WIND DIRECTIONS IN DEGREES TRUE
WIND SPEEDS IN KNOTS
SYSTEM MOTION SPEEDS IN KNOTS
WAVE HEIGHTS IN FEET
WAVE PERIODS IN SECONDS
TEMPERATURES IN DEGREES CELSIUS
VISIBILITIES IN NAUTICAL MILES

WIND CRITERIA

LIGHT – SPEEDS 0 TO 11 KNOTS
MODERATE – 12 TO 19 KNOTS
STRONG – 20 TO 34 KNOTS
GALE – 35 TO 47 KNOTS
STORM – 48 KNOTS AND GREATER

NOTE: GALE AND STORM WARNINGS ARE ISSUED WHEN THE MEAN WINDS ARE EXPECTED IN THE APPROPRIATE CATEGORIES.

VISIBILITY CRITERIA

POOR – ZERO TO 1 MILE
FAIR – MORE THAN 1 MILE BUT LESS THAN 6 MILES
GOOD – 6 MILES OR MORE

ICING DUE TO FREEZING SPRAY

LIGHT – 1 TO 3 CM PER 24 HR.
MODERATE – 4 TO 6 CM PER 24 HR. (WARNING ISSUED)
HEAVY – 7 TO 14 CM PER 24 HR.
VERY HEAVY – 15 CM OR GREATER PER 24 HR.

WEATHER ABBREVIATIONS

R – RAIN
RW – RAINSHOWER(S)
TRW – THUNDERSHOWER(S)
S – SNOW
SW – SNOWSHOWER(S)
L – DRIZZLE
ZR – FREEZING RAIN
ZL – FREEZING DRIZZLE

IP – ICE PELLETS
IPW – ICE PELLET SHOWER(S)
SP – SNOW PELLETS
A – HAIL
M – MIST
F – FOG
H – HAZE

PRECIPITATION QUALIFIERS

(–) LIGHT
(   ) MODERATE
(+) HEAVY

SKY COVER TERMINOLOGY

CLR – CLEAR	The sky condition when no cloud or obscuring phenomena is present.
-X - PARTIALLY OBSCURED	A surface based layer with a summation opacity of at least 1/10 but less than 10/10.
X – OBSCURED	A surface based layer with a summation opacity of 10/10
SCT – SCATTERED	A layer aloft with a summation amount of 5/10 or less.
BKN – BROKEN	A layer aloft with a summation amount of 6/10 to 9/10 inclusive.
OVC – OVERCAST	A layer aloft with a summation amount of 10/10.

INTERPRETATION OF OUTLOOK FORECAST

The outlook forecasts focus on the 6 to 12 hour period of each day during which the wind is expected to be the strongest and subsequently for that period the following parameters are forecast – the average wind speed and direction, the prevailing visibility and the combined sea state.

Item E-4
Description of February 14-15, 1982 Storm

This storm was first identified on the surface chart at the Atlantic Weather Centre in Bedford, Nova Scotia on February 12th as a weak disturbance in the Gulf of Mexico. The disturbance moved off the coast of Georgia and developed as it moved northward following the track shown in Figure 1. By 14/0000Z[1] the low had moved to about 210 nautical miles (nmi) south of Halifax. The low then began to intensify rapidly and moved toward the Avalon Peninsula at a speed of 35 knots passing near St. John's, Newfoundland at 1800Z. The low then continued to move northeastward with little or no deepening. By 0000Z on February 15 the low was located about 180 nmi northeast of St. John's. The Surface Analyses (Figures 2-7) plot the movement of this low pressure system from 0000Z, February 13 to 1200Z, February 15, 1982.

Winds from this storm began to affect the Hibernia area about 14/0600Z. They continued from the southeast at 30 to 50 knots until shifting to the southwest and increasing at about 14/1600Z. The strongest winds reported by drill rigs on the Hibernia field were the southwest winds between approximately 14/1600Z and 15/0600Z. At this time the low was passing to the northwest of the drill site. A maximum wind of 78 knots with gusts to 91 was reported by the *SEDCO 706*, located about 10 nmi northeast of the *Ocean Ranger*.

As the low moved northeastward into the North Atlantic the winds veered to the west or northwest and diminished slightly. West gales persisted in the area until approximately 0900Z on the 16th.

Sea states reported in weather observations for this storm were the highest recorded by the *Ocean Ranger* since it began reporting from Newfoundland waters in November 1980. The maximum state was a sea of 10 metres combined with a swell of 7 metres. This was at 15/0300Z, the last report received from the drill rig.

A more detailed meteorological discussion of the life cycle and dynamics of this storm is included in the "Detailed Analysis of the February 14-15, 1982 Storm" section of this report.

TRACKS OF MAJOR STORMS AND SUMMARY

The tracks of the major low pressure systems in the vicinity of the *Ocean Ranger* and of the storm during which the *Ocean Ranger* sank are shown in Figure 1. These storms all produced winds at the *Ocean Ranger* site in excess of 55 knots. The durations of strong winds and the maximum winds and sea states reported in the synoptic and intermediate synoptic weather observations at the *Ocean Ranger* site during these major storms are summarized in Table 1. The last column in this table shows the maximum combined wave height reported in these weather observations. It should be noted that combined wave heights are a function of other factors in addition to wind speed, e.g., wind duration, fetch, swell waves from remote storms and water depth. Thus, in most cases, there is not a one-to-one correlation between wind speed and wave height. With the exception of the September storm (Storm #3), these storms all occurred in the winter months of December, January and February – the time of year when the greatest north-south thermal contrast in the atmosphere occurs and when extra-tropical cyclonic activity is, in consequence, usually most intense. The storms generally moved in a northeasterly direction from their origin over the continent or the warm waters of the Gulf Stream.

In addition to eight cyclones there are numerous examples from other years of intense disturbances, strong winds and high seas over the Grand Banks (e.g., hurricane GEORGES of September 8, 1980). The marine archives have been searched for a small area centred at 46.8N 48.8W for examples of wind reports in excess of 63 knots in the Hibernia area. These examples are listed in Table 5. From examination of storm tracks (Figure 1) and the data in Table 2, it is apparent that the storm of February 14-15, 1982 was not an exceptional occurrence in this area of the world.

The storm of February 14-15, 1982 over the Grand Banks was a severe one. However, the storm track information (Figure 1), the extreme wind data in Tables 1 and 4 and other available data suggest that this storm was typical of severe winter storms over the Grand Banks. The evidence shows that storms of comparable severity have occurred in the past and probably can be expected in the future.

OCEAN RANGER STORM DESCRIPTION
DETAILED ANALYSIS OF FEBRUARY 14-15, 1982 STORM

The storm which brought hurricane force winds to the Grand Banks area off Newfoundland on February 14th and 15th was first analysed by meteorologists at the Atmospheric Environment Services's Atlantic Weather Centre and Newfoundland Weather Office when it was a weak disturbance in the Gulf of Mexico on February 12th. This weak disturbance moved off the coast of southern Georgia that evening. An area of weak positive vorticity advection (PVA)[2] was just to the northwest of the low centre. Cold air advection at low levels behind the disturbance, a cross contour component of the 500 millibars (mb) winds and a favourable location of the low with respect to a strong 250 mb jet all suggested that this disturbance should develop.

By 13/1200Z the low had deepened to 1002 mb. At this time the 500 mb short wave trough had taken on a northwest to southeast orientation about 4 degrees of latitude behind the surface low, with the southeastern portion of the PVA now over the surface low position. The 1000 to 500 mb thickness ridge started to amplify and lay midway between the 500 mb trough and ridge. A 150 knot jet maximum[3] had developed just east of Boston and the surface low was situated under a west-southwest flow of 120 knots in the right entrance area of the jet stream core.

At 14/0000Z the central pressure of the low was 984 mb and it had moved to 210 nmi south of Halifax. By 14/1200Z the low was located just south of St. Pierre-Miquelon. The low had moved to the north side of the jet stream axis and the 500 mb trough was beginning to close off. The thickness ridge was just east of the 500 mb trough and had reached its maximum amplitude. After this time the thermal ridge occluded from the low. The low continued to deepen for about the next 6 hours due almost exclusively to 500 mb height falls.

By 14/1800Z the low was located near St. John's. The central pressure at this time was about 954 mb. This was about the maximum stage of development of the low and after this time the low moved northeastward at a speed of 25 to 30 knots with little deepening or filling taking place.

The detailed sequence of meteorological events during February 14th and 15th at the three rigs in the Hibernia area is graphed in

Figures 8 to 13. Data for these plots was extracted from the coded weather observations received at the Newfoundland Weather Office and observations recorded in the log books of the *SEDCO 706* and the *Zapata Ugland*.

A frontal system which occluded from the low south of Nova Scotia moved east-northeastward faster than the motion of the low itself. A trough of warm air aloft (trowal) extending northward from the frontal wave passed over the *Ocean Ranger* between 1500Z and 1600Z. At this time (see Figure 9) the southeast winds gradually veered from south to west as the low moved away to the northeast. They steadily increased in speed reaching a maximum at about 14/2100Z then diminished slightly after 15/0000Z. Temperatures increased to about 4°C in the southerly winds then fell gradually as winds changed to westerly. Breaks in the cloud cover were reported by all three drilling rigs as a narrow clear area (dry slot) moved over the area. The dry slot was between the thick cloud associated with the trowal and low level circulation cloud.

After about 15/0300Z the winds stabilized to a westerly direction and slowly diminished in strength, although gale force winds persisted until about 0900Z on February 16th. Circulation-induced unstable cumulus, or towering cumulus, formed over water in the cold westerly flow in the wake of the storm.

Precipitation in the form of heavy snow began at the *Ocean Ranger* at 14/0900Z. As temperatures rose the snow changed to moderate rain at 14/1400Z. Rain and fog continued throughout the day then reverted to snow later in the afternoon as temperatures fell below the freezing point. Light freezing rain was reported (on 15/0000Z) by the Ocean Ranger during the transition period.

After 15/0000Z the predominant restriction to ceiling and visibility was snow, although rain mixed with the snow was reported at the *Zapata Ugland* until 0730Z. Snow of varying intensity (and thus variable visibility) continued throughout the day on February 15th until it ended at approximately 0300 – 0600Z on February 16th. The time series of ceilings and visibilities in Figures 12 and 13 show that on February 15th the cloud ceiling varied between 300 and 1000 feet. Cloud ceilings and visibilities reported in the area were also low during the period from about 14/1900Z until the disappearance of the rig.

Any snow which accumulated on the rigs before 14/1400Z would likely have melted during the 5 to 6 succeeding hours of above freezing temperatures and rain. It is not likely that there was much accumulation of freezing rain as it was not reported by either the *Zapata Ugland* or the *SEDCO 706* and the time frame during which freezing rain could have occurred was quite short.

Using the criteria for freezing spray of Table 3, weather conditions after 15/0000Z at the *Ocean Ranger* were favourable for the occurrence of freezing spray. Various studies have been done relating the rate of vessel icing to meteorological and sea state parameters (see for example Comiskey [1976], Shellard [1974], Stallabrass [1980], Kachurin et al [1974]). Using the combination of wind speed, air and sea surface temperatures observed at the *Ocean Ranger* at 15/0300Z the nomograms[4] of Comiskey [1976] and Shellard [1974] both predict heavy to very heavy icing. Since icing rate or severity is highly dependent on vessel shape and speed (Stallabrass [1980]) it is impossible under the confines of the AES examination, to make a reliable quantitative estimate of icing rates on the *Ocean Ranger* from the physical data alone. The other rigs in the area (*SEDCO 706* and *Zapata Ugland*) were exposed to similar environmental conditions (see Figures 8-13). It is suggested that freezing spray conditions (if any) observed on these drilling rigs would be similar to that on the *Ocean Ranger*.

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[1] When indicating dates and times in its reports, AES uses the standard format of "day/time Zulu" with Zulu time (Greenwich Mean Time) being local time plus 3½ hours i.e. 14/0600Z reads 0600 Zulu on Feb. 14.

[2] PVA is the rate of increase in counterclockwise rotation of the atmosphere in the vicinity of a storm, due to transport of rotating air by upstream air currents; essential for the development or intensification of storms.

[3] A "jet stream" is relatively strong winds concentrated within a narrow stream in the atmosphere. A MAXIMUM JET is the maximum wind speed that occurs in a jet stream.

[4] Graphical presentation of relations between quantities whereby value of one may be found by simple geometrical construction from those of others.

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TABLES

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* From original report

TABLE 1 Duration of strong winds, maximum winds and combined wave heights from weather reports of the *Ocean Ranger* during nine severe storms over the Grand Banks of Newfoundland.

	Duration (in hours) of			
Storm**	Gales (≥34 kts.)	Storms (≥48 kts.)	Maximum Wind (kts.)	Maximum Wave Height (m)
Storm #1	27	18	56	6.5
Storm #2	21	3	56	5.5
Storm #3	51	21	61	7.0
Storm #4	12	3	65	6.7
Storm #5,6	48	39	67	9.0
Storm #7	72	30	56	9.0
Storm #8	18	6	56	6.5
Ocean Ranger storm	n/a (48)*	n/a (33)*	72 (78)*	12.2 (12.0)*

*Bracketed values are from observations of the *Zapata Ugland* (47.0°N 48.8°W)

**Storm #1 – November 28, 1980
Storm #2 – December 14, 1980
Storm #3 – September 27, 1981
Storm #4 – January 10, 1982
Storm #5, 6 and 7 – January 15-20, 1982
Storm #8 – February 7, 1982
The *Ocean Ranger* Storm – February 14-15, 1982

TABLE 2 Number of days that wind exceeded a given threshold at the *Ocean Ranger*, November 6, 1980 – February 15, 1982.

CATEGORY	NO. OF DAYS	PERCENT OF TOTAL
≥34 kts. (gale force)	197	42.4%
≥48 kts. (storm force)	43	9.2%
≥56 kts. (violent storm force)	13	2.8%
≥64 kts. (hurricane force)	4	0.9%

TABLE 3 Combined Frequency of Occurrence of Temperatures ≤ – 2°C and Winds ≥22 Knots at the *Ocean Ranger*

Month	Year	Percent of Time
December	1980	10.1%
January	1981	4.4%
February	1981	8.0%
March	1981	0.4%
April	1981	0.8%
December	1981	6.0%
January	1982	17.7%
February*	1982	32.7%

*Based on February 1-15 only.

Note: When temperatures fall below -2°C and winds exceed 11 m sec^{-1} (11 metres per second or 22 knots) the occurrence of freezing spray is possible. Weather conditions reported by the *Ocean Ranger* were analyzed to determine the percentage of time during which this condition existed in the vicinity of the rig.

TABLE 4 Examples of observations of wind speed exceeding 63 knots over the Hibernia area*, 1960-1979.

DATE	TIME	WIND	
		DIRECTION	SPEED (KNOTS)
Oct. 28, 1973 (+)	1200Z	310	86
Feb. 5, 1976	1800Z	040	74
Nov. 30, 1974 (+)	0000Z	040	70
Nov. 24, 1973 (+)	0600Z	360	70
Dec. 28, 1972 (+)	1800Z	200	70
Feb. 16, 1966	1200Z	290	68
Feb. 16, 1966	1500Z	290	68
Feb. 16, 1966	1800Z	290	68
Nov. 24, 1973 (+)	0000Z	340	66
Dec. 26, 1974	1800Z	360	65
Oct. 22, 1973 (+)	1200Z	360	65
Jan. 3, 1975	0000Z	160	64

*Hibernia area is enclosed by the following Latitude – Longitude Pairs:

45.8N	48.0W	47.8N	49.7W
45.8N	49.7W	47.8N	48.0W
46.8N	50.2W	46.8N	47.4W

(+) Oil Rig Observations

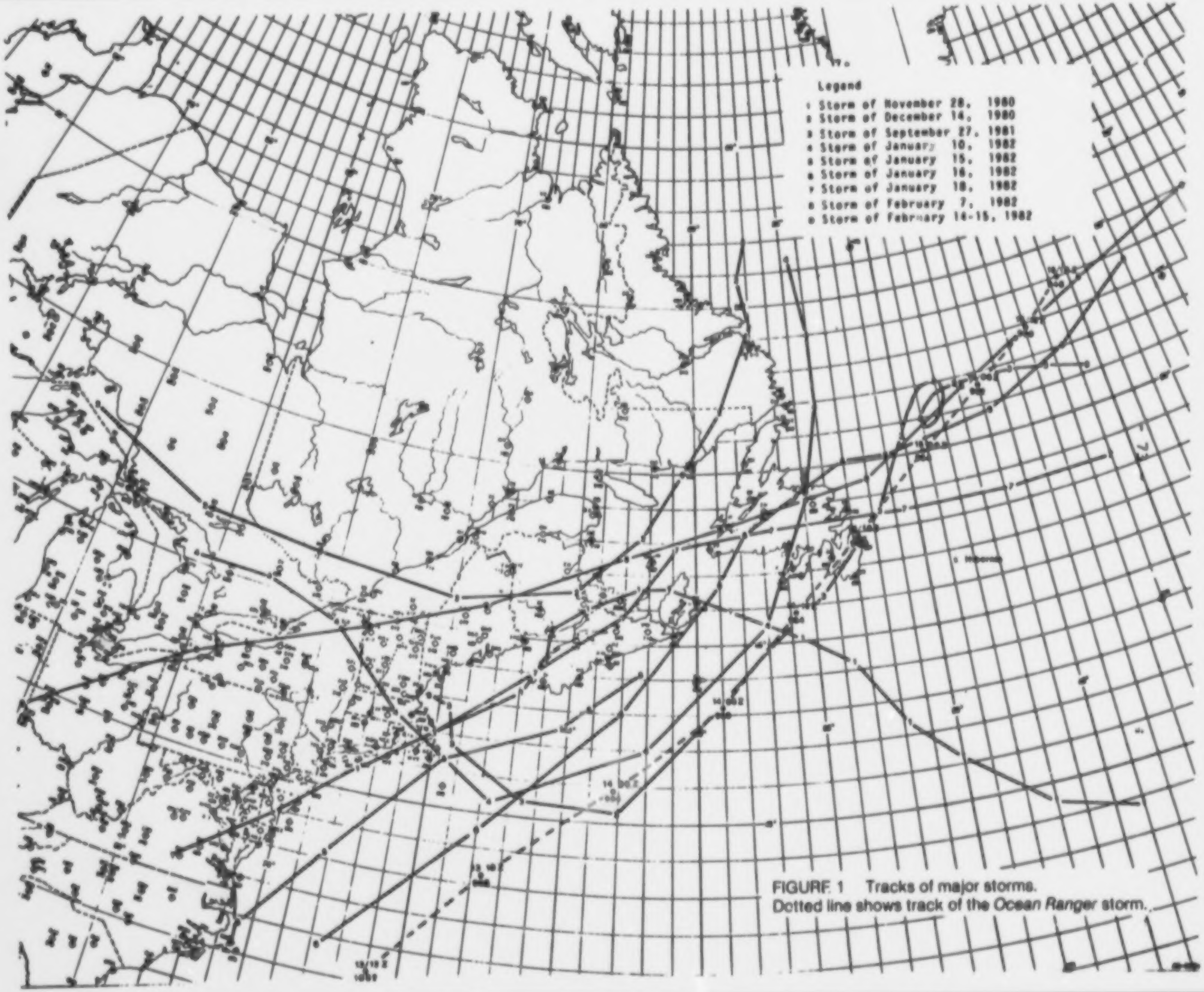
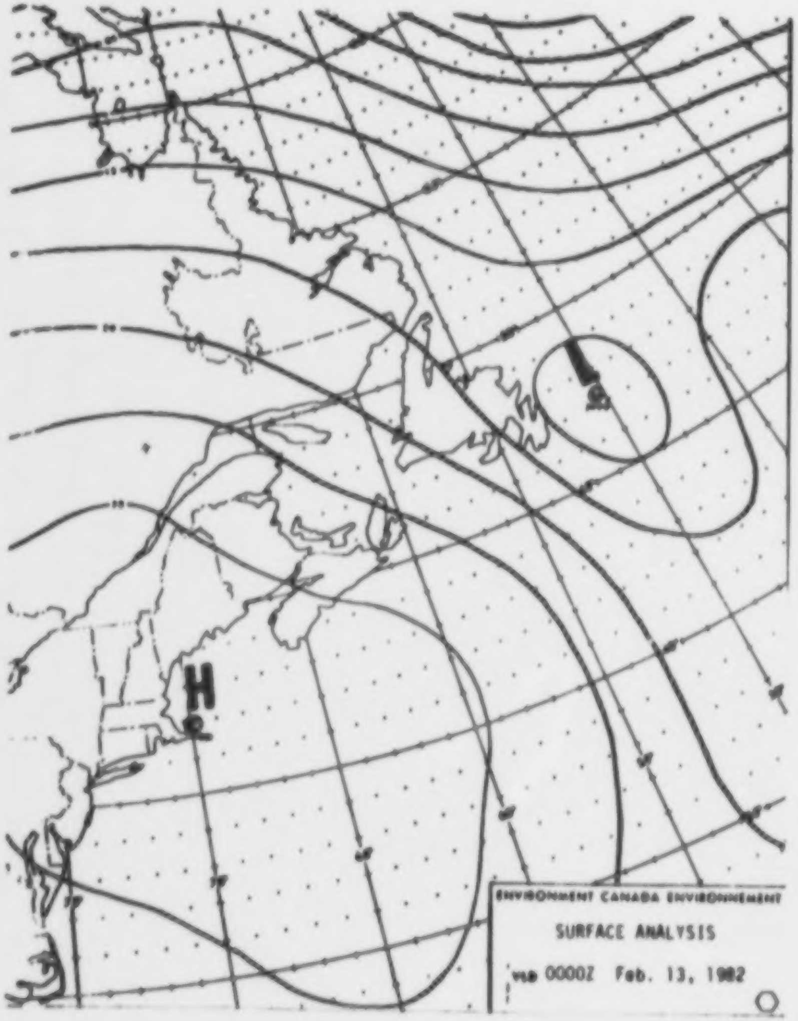

Legend
1 Storm of November 28, 1980
2 Storm of December 14, 1980
3 Storm of September 27, 1981
4 Storm of January 10, 1982
5 Storm of January 15, 1982
6 Storm of January 16, 1982
7 Storm of January 18, 1982
8 Storm of February 7, 1982
9 Storm of February 14-15, 1982
Hibernia

FIGURE 1 Tracks of major storms.
Dotted line shows track of the *Ocean Ranger* storm.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SURFACE ANALYSIS
VIB 0000Z Feb. 13, 1982
L
H

FIGURE 2

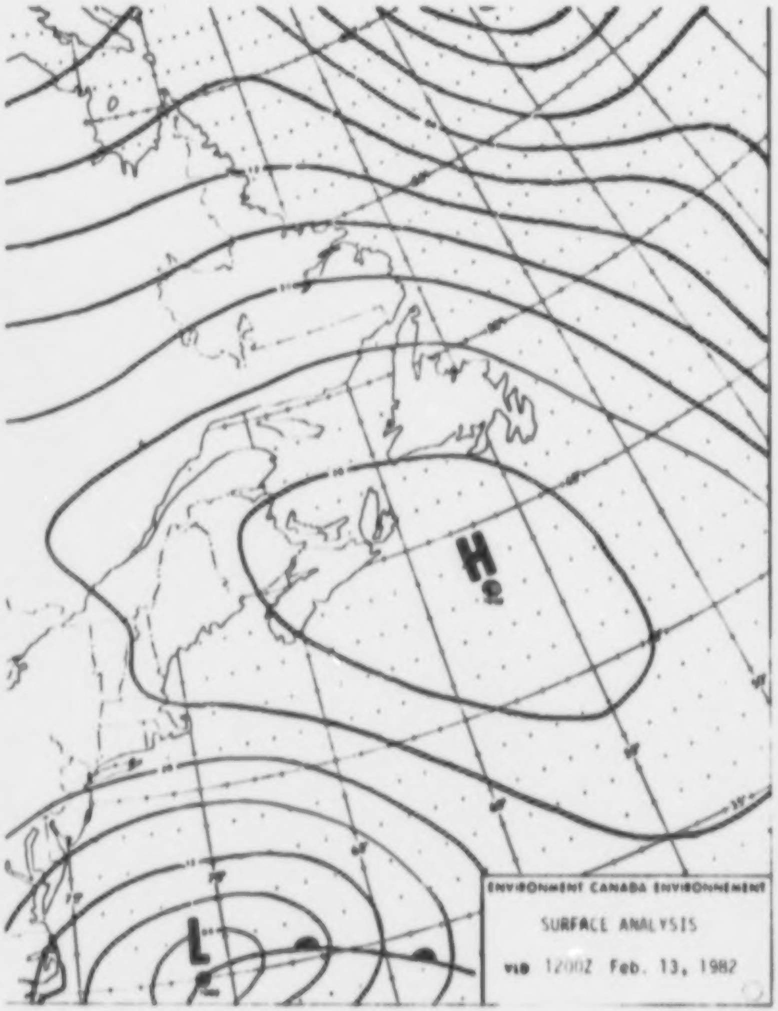
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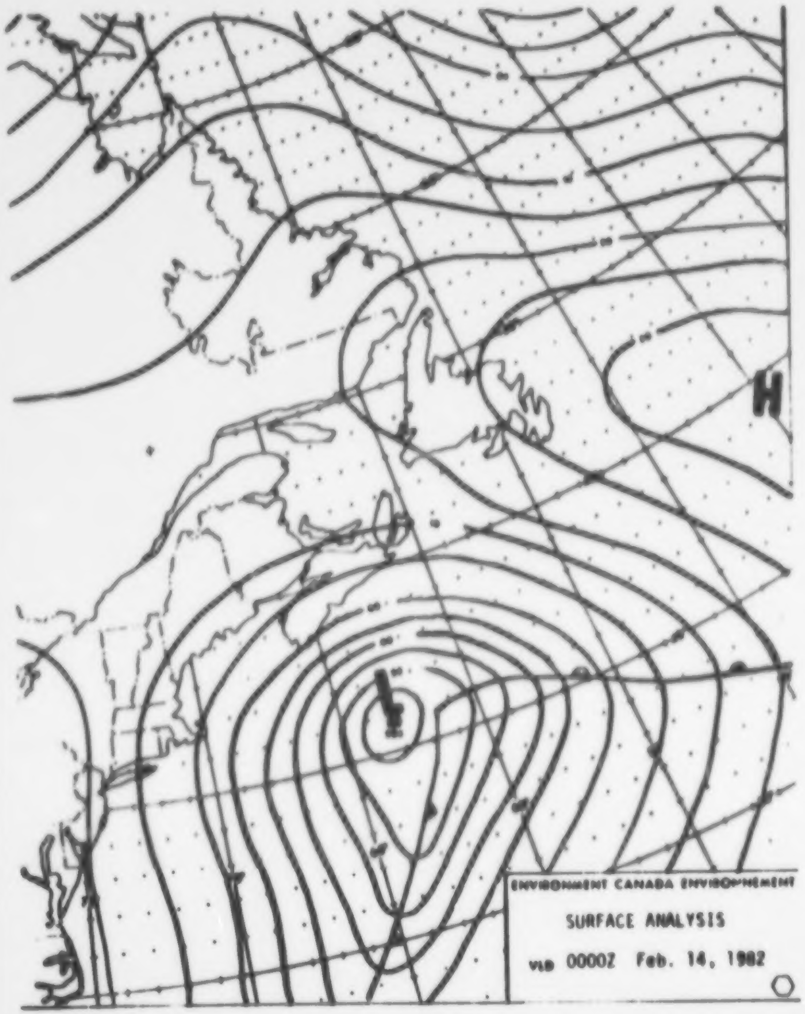
FIGURE 3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SURFACE ANALYSIS
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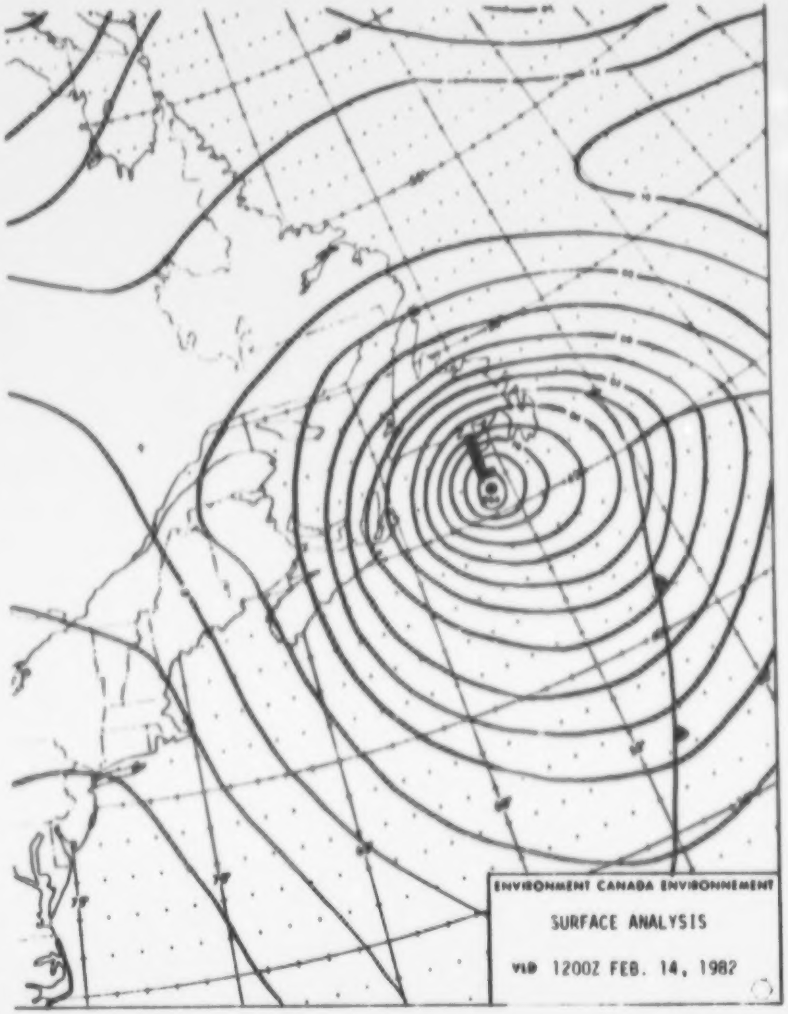
FIGURE 4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SURFACE ANALYSIS
VLD 1200Z FEB. 14, 1982

FIGURE 5

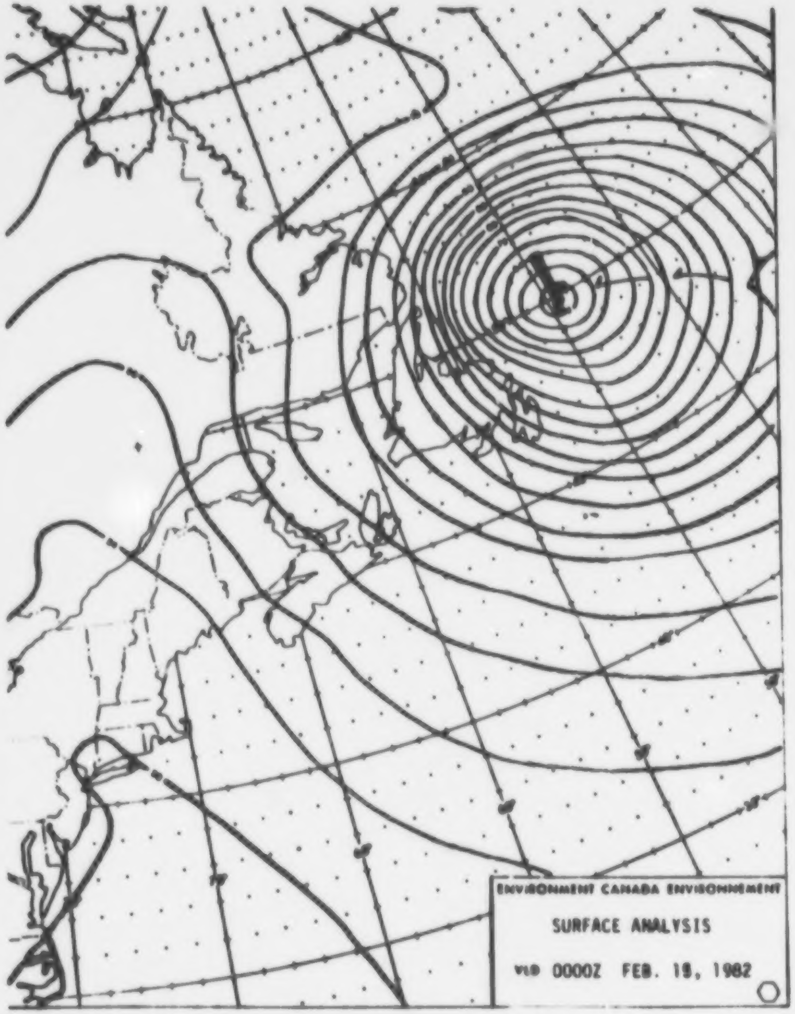
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FIGURE 6

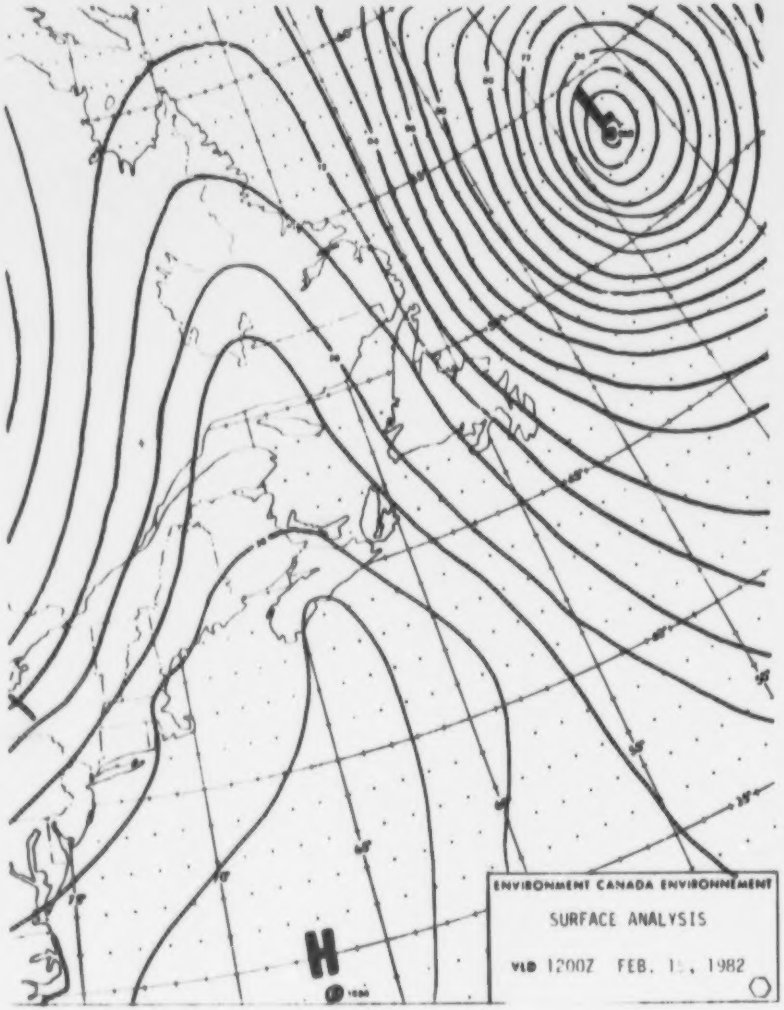
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FIGURE 7

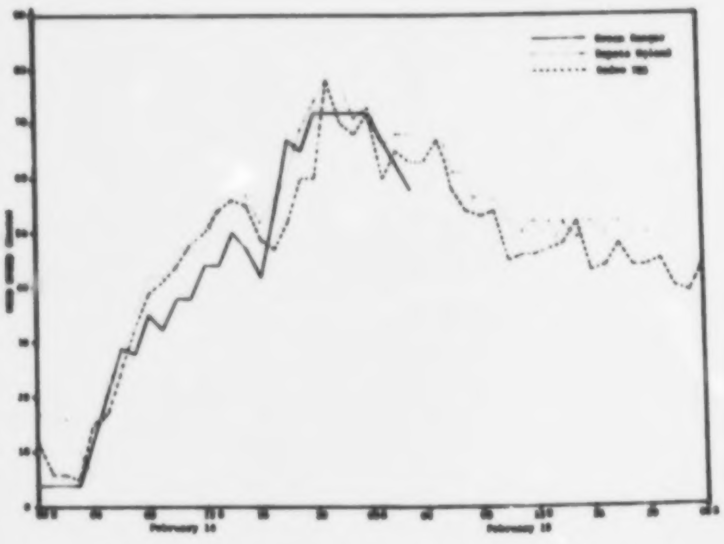
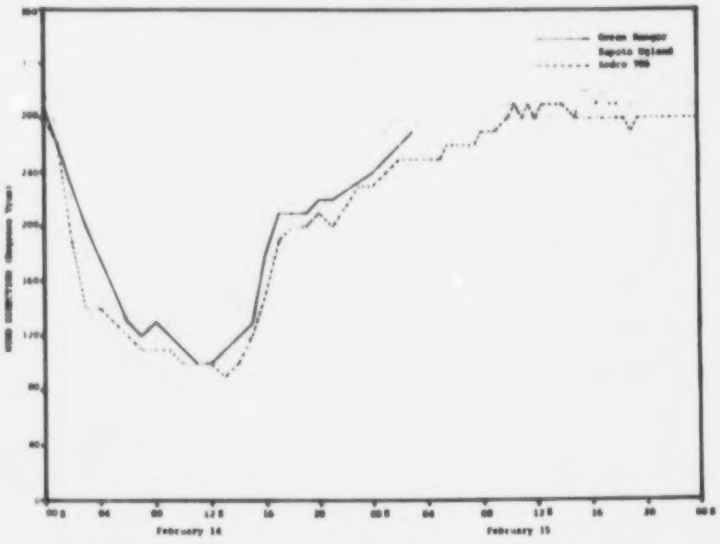


FIGURE 8 Wind speed at Hibernia, February 14-15, 1982.



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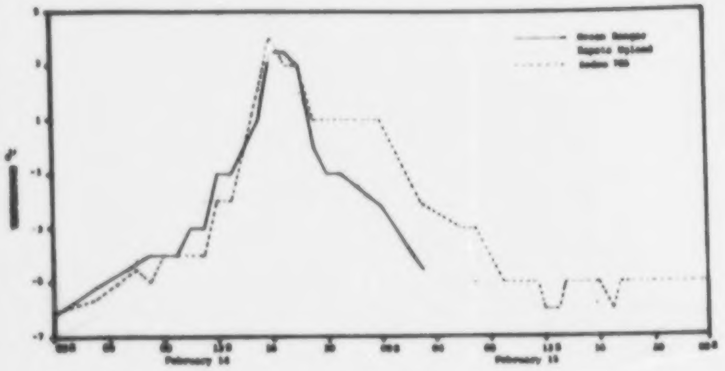

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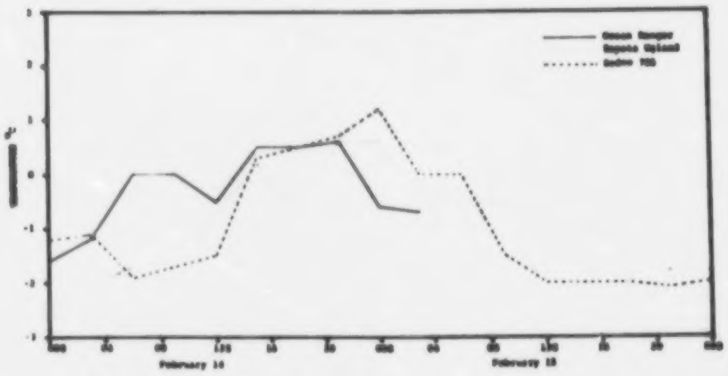


FIGURE 11 Sea surface temperature at Hibernia, February 14-15, 1982.

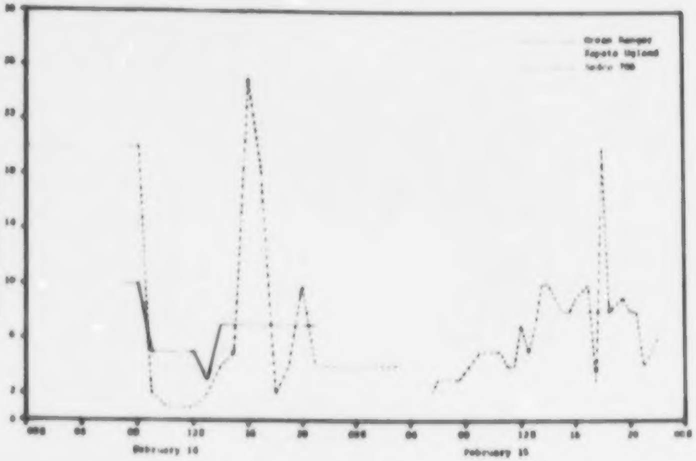
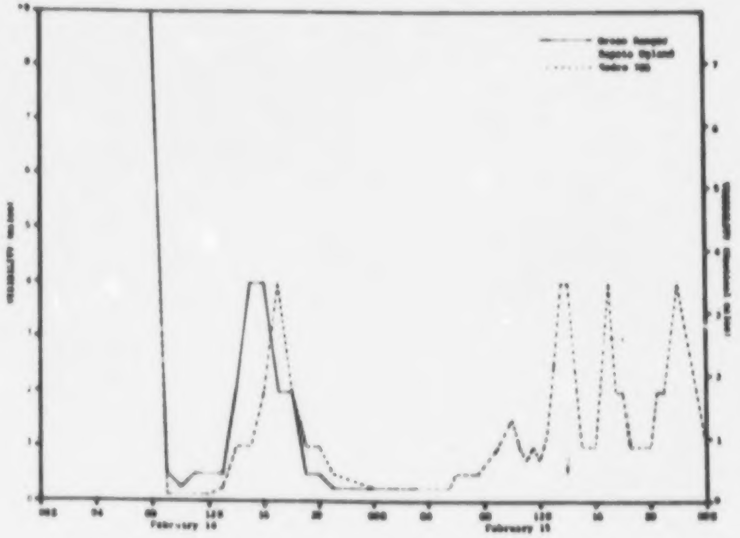


FIGURE 12 Height of ceiling at Hibernia, February 14-15, 1982



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Item E-5
Wave Data from the *Zapata Ugland*,
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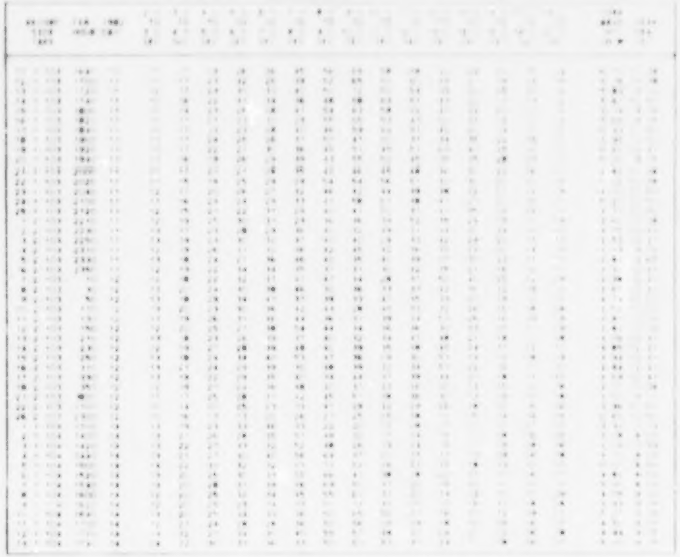
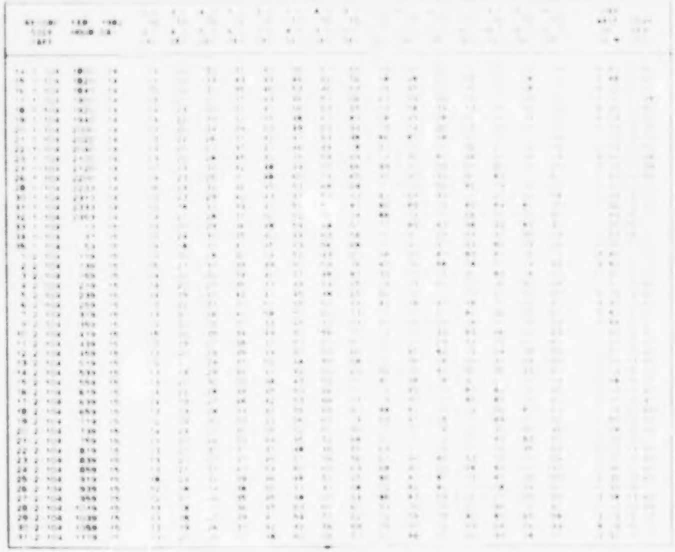
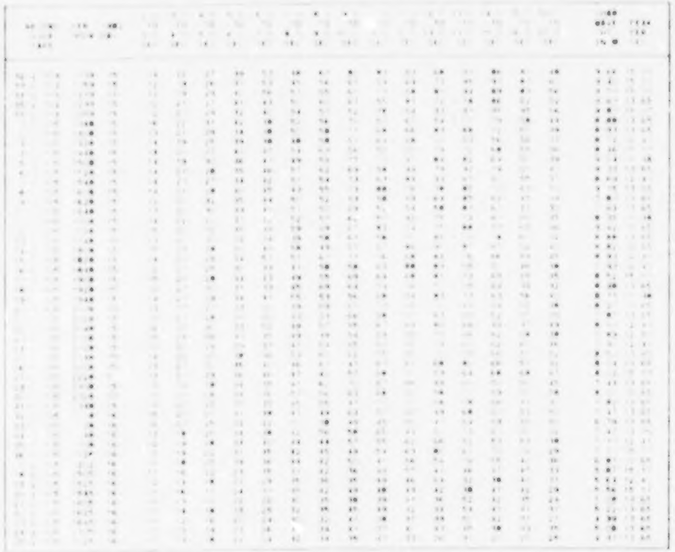




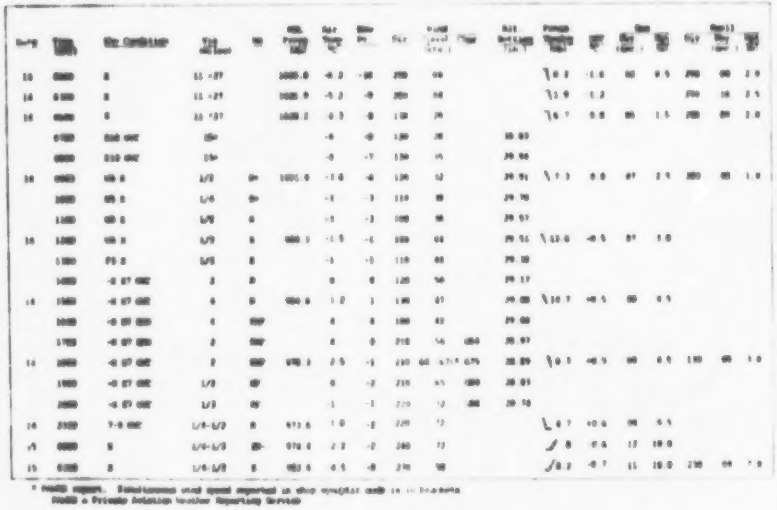


Item E-6

Weather Observations for February 14, 15, 1982 from the Zapata Ugland, SEDCO 706, Ocean Ranger.

Zapata Ugland

SEDCO 706



Ocean Ranger

Time (GMT)	MEASURED WIND (KNOTS)	10-METRE WIND SPEED* (KNOTS)
141200	44	37
1300	44	37
1400	50	41
1500	47	38
1600	42	33
1700	54	43
1800	60	48
1900	65	53
2000	72	58
2100	72	58
150000	72	58
0300	58	48

10-metre wind speeds at the *Ocean Ranger* site on February 14 and February 15, 1982

Time (GMT)	MEASURED WIND (KNOTS)	10-METRE WIND SPEED* (KNOTS)
140900	41	34
1000	44	37
1100	48	40
1200	50	41
1300	54	44
1400	56	46
1500	55	45
1600	49	39
1700	47	37
1800	52	42
1900	60	49
2000	60	49
2100	78	62
2200	70	56
2300	68	55

10-metre wind speeds at the *SEDCO 706* (WVFN) drill site on February 14, 1982

*Derived from measured wind, air and sea surface temperatures and the tables of S.D. Smith (1981). *Factors for Adjustment of Wind Speed Over Water to a 10-Metre Height.* B.I.O. Report BI-R-81-3 March 1981

TECHNICAL DATA

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APPENDIX F

TECHNICAL DATA

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Item F-1
Re-Entry and Suspension of Hibernia J-34

46° 43' 33.84" N
48° 50' 13.00" W

Submitted by:

R.M. Harvey, P.Eng.
D.C. Strong, P.Eng.
E.P. Lannon, B.Sc. (Geology)

Canada Oil and Gas Lands Administration
St. John's, Newfoundland
July 15, 1982

INTRODUCTION

This report describes operations undertaken by Mobil Oil Canada Limited and Neddrill to suspend the Mobil et al Hibernia J-34 well following loss of the *Ocean Ranger*. It was prepared by the engineering staff of the St. John's office of the Canada Oil and Gas Lands Administration (COGLA) who witnessed the operation. Their primary duties during the suspension were as follows:

- document condition of the *Ocean Ranger* BOP stack prior to re-entry;
- witness re-connection to the BOP stack and removal of the drill string;
- note location of the hang-off point with respect to the sheared end of the pipe to confirm that the string was hung-off on the proper rams;
- inspect sheared end to ensure proper operation of the shear rams;
- witness measurement of the drill pipe removed from the well to ensure that the drill bit had been pulled back into the casing before the pipe was sheared;
- witness setting of mechanical/cement plugs before removal of the BOP stack;
- ensure that the *Ocean Ranger* wreckage was not disturbed during the suspension operation.

Units used throughout are English, as this was the system used during the re-entry and suspension program.

BACKGROUND

On February 15, 1982 at approximately 0300 hrs. the semisubmersible drilling unit *Ocean Ranger* sank during a storm on the Grand Banks with the loss of all hands. The unit, owned and operated by the Ocean Drilling and Exploration Company Limited (ODECO) and its subsidiary, ODECO of Canada Limited, was under contract to Mobil Oil Canada to drill the Mobil et al Hibernia J-34 well approximately 3 miles WSW of the P-15 discovery well. Drilling had commenced on November 27, 1982 and had progressed to 12169 ft. by 1600 hrs. on February 14, 1982 (all depths relative to the *Ocean Ranger* rotary table (RT) elevation). Total depth for the J-34 well was projected to be 14,000 ft.

During the evening of February 14, 1982 the *Ranger* reported that, due to deteriorating weather conditions and mechanical difficulties, it was forced to disconnect the marine riser and the lower marine riser package (LMRP) from the BOP stack, using the shear rams to cut the drill string. The drill bit was reported to have been lifted off bottom and pulled up into 9⅝ inch diameter casing which had been run to a depth of 12014 ft. Prior to shearing, the drill string was reported to have been hung-off on the middle pipe rams, located 6.5 ft. below the shear rams.

After having cut the drill pipe, enabling removal of the LMRP from the BOP stack, the shear rams were left in a closed position, thereby preventing escape of well fluids should hydrostatically underbalanced formations be exposed in the open hole, although lithology indicated the 155 ft. of open hole to be devoid of oil or gas bearing zones.

Subsequent to the sinking of the *Ocean Ranger* the BOP stack was examined from the vessel *Balder Cabot* using a remote controlled vehicle (RCV) equipped with a video camera. This inspection showed the only visible damage to be a bent guidepost. These guideposts are used to guide the LMRP onto the BOP stack during re-connection operations. In addition, the BOP stack was found to be free from debris, with the exception of one piece of drill pipe resting against it.

On June 1, 1982 COGLA approved the proposal prepared by Mobil for re-entry and suspension of the J-34 well. This was done with the concurrence of the *Ocean Ranger* Royal Commission.

ARRIVAL ON-SITE AND ANCHOR DEPLOYMENT

The drillship, *Neddrill 2*, was contracted by Mobil to carry out the suspension operation. It left St. John's on June 4, 1982 at 0300 hrs., arriving on location 1955 hrs. the same day. Several days prior the *Balder Cabot* had placed a sonic beacon belonging to *Neddrill 2* on the BOP stack using a 1 atmosphere Mantis submersible. The *Cabot* had also at this time set out an anchor pattern for the drillship.

Upon arrival at the wellsite the *Neddrill 2* deployed four anchors. COGLA representative, E.P. Lannon, sailed onboard the vessel from St. John's and witnessed deployment of the anchors. He was relieved by R.M. Harvey at 1730 on June 5, 1982.

In order to improve their holding capacity the anchors were permitted to settle into the seafloor for several hours. A tension of 100 tons was then applied to each. Anchor No. 6 would not hold and had to be run out an additional 1000 ft. on the same heading. The anchors' cables were then slacked off and the vessel held on location using the dynamic positioning system. The anchoring system would be used only to prevent the vessel being pushed over the wreck by wind or wave forces should the electrical system fail, thereby endangering the marine riser or the diving bell if these were lowered at the time.

RE-CONNECTION

At 0020 hrs. on June 6, 1982 the diving bell left the surface with two Can Dive divers in saturation. The first of the divers' tasks was to set sonic beacons for the dynamic positioning (DP) system. This was accomplished by 0230 hrs. At approximately 0300 hrs. the DP system lost the signal from the beacons, apparently due to the divers' bubbles. The vessel switched to its taut wire backup while this problem was rectified. The *Ocean Ranger* beacon was removed from the BOP stack at this time and brought to the surface.

At 0420 hrs. guidelines 2 and 4 were run down and attached to the top of the BOP guideposts. The bent No. 3 guidepost was then cut off and the lower marine riser package jig run down to bottom. The purpose of this jig was to measure the distance from the stack centre to the centre of the control pod receptacle and choke and kill connections to ensure that the LMRP constructed for the project would fit the stack.

At 1200 hrs. the jig was located over the stack and connection attempted. It was discovered, however, that a second guidepost was also bent (No. 4) and the jig would not seat properly. The jig was pulled back up and, as the divers were experiencing some difficulties with their communications gear, they were forced to return to the surface as well so that maintenance could be performed on the bell.

Several attempts were made during the afternoon and evening of June 6 to modify the jig and land it without the aid of divers. These attempts were not successful.

At 0545 hrs., June 7, the divers were sent down to cut post No. 4. This was completed by 0630 hrs. and the jig landed. The feeler gauges were set on the pod receptacle and the choke and kill connections. Examination of the jig's position on the stack showed it to be slightly off centre and tilted, indicating that the two remaining guideposts were also slightly bent and would, therefore, have to be removed.

By 1050 hrs. the jig was recovered. Measurement of the feeler gauges indicated no significant differences between the connection positions on the original LMRP and the new unit.

At 1115 the divers began attaching tags to the hydraulic hoses on the BOP stack to identify the function of each line. This was necessary as modifications may have been made to routing of the hoses from the pods to the various pieces of equipment which may not have been shown on diagrams of the BOP system.

The following lines were tagged both "open" and "close":

annular preventer
shear rams
upper pipe rams
middle pipe rams
lower pipe rams
outer kill
inner kill
upper outer choke
upper inner choke

The lower H4 connector had three lines: primary latch and primary/secondary unlatch.

At 1600 hrs. on June 7 the new LMRP was picked up and positioned in the moonpool as assembly of the marine riser commenced. This assembly was complete at midnight at which time an attempt was made to latch the connector. This effort succeeded at 0030 hrs. on June 8 when additional weight was applied to the LMRP. By 0630 hrs. all of the hydraulic lines were disconnected, function tested and reconnected, confirming proper hose routing.

OPENING OF SHEAR RAMS AND RE-CONNECTION TO DRILL STRING

Following connection of the LMRP to the BOP stack the choke and kill lines were pressure tested successfully to 4500 psi (both lines held this pressure). The choke line was then pressurized to about 550 psi and the valves opened. The pressure dropped indicating that there was no pressure under the shear rams. The kill line was then pressurized up to 500 psi and opened. The pressure dropped to 100 psi. This pressure is attributable to thermal stresses and is not considered significant.

By 0840 on June 8 the well was being circulated through the upper choke, down through the drill string, up the annulus and out the kill line. The pressure on the pumps was 1300 psi, the flow rate was about 50 gallons per minute. Brine at a weight of 9.2 pounds per gallon was pumped down. The returning mud had a weight of 9.1 to 9.2 pounds per gallon.

At 1335 on June 8 the shear rams were opened and the milling tool run to grind off the top of the sheared pipe. Three joints of drill collar and 5 joints of drill pipe were used.

By 1500 hrs. the mill had been turning for about one half hour without progress. It was decided to pull it out of the hole to examine it. When it was brought out it was found to have a piece of drill pipe wedged in its throat together with the top of a hang-off tool.

The crew of the *Ocean Ranger* thus had pulled up, inserted the hang-off tool in the drill string and had run this tool back down to the BOP stack, landing it on the closed middle pipe rams. Before the top of the hang-off tool could be uncoupled, however, the shear rams were closed, cutting the drill string.

Therefore, when the clockwise rotating mill engaged the top of the sheared pipe it had unscrewed the left-handed thread of the hang-off tool, disengaging it from the bottom half of the tool. Further rotation only damaged the threads of the tool. When the mill was removed the top of the sheared pipe was recovered.

A number of attempts were made during the evening of June 8 to re-connect the hang-off tool. These attempts were unsuccessful. At 0630 hrs. on June 9, the drill crew succeeded in re-connecting to the bottom portion of the hang-off tool, using another undamaged hang-off tool top. Tension was then applied, reaching 320,000 pounds (compared with a total string weight of 350,000 pounds) before the connection parted. Examination of the threads of the hang-off tool indicated that it had been only partially engaged.

At 0700 hrs. another attempt was made. Four equally spaced grooves were ground at right angles to the threads of the original hang-off tool. This was then sent down and screwed into the bottom part of the tool. Mobil was concerned that this connection would part a second time and therefore decided to strip the pipe through closed pipe rams, that is, keep one set of rams closed at all times while the pipe was being pulled from the hole. Thus, if the connection parted, the large diameter cylindrical bottom of the hang-off tool would be stopped by the pipe ram, probably causing the string to break just below it. With the hang-off tool then removed from the drill string, retrieval of the drill pipe from the hole would be greatly simplified.

At 1900 hrs. on June 9 tension was applied to the drill string. Rams No. 3 and 4 were both closed. A tension of 370,000 pounds was necessary before the string started to move. At 0100, June 10, the hang-off tool was recovered and removed from the drill string. The combined length of the hang-off tool and sheared pipe was 77¼ in., which is the distance between the middle pipe ram and the shear ram.

After removal of the hang-off tool, the drill string was run down to bottom to determine the depth the *Ocean Ranger* had reached. When this was accomplished, the pipe was removed from the hole, laid down and measured. The measurements are as follows:

NEDDRILL	
5 stands drill pipe	502
1 single DP	
down on kelly	22
	524 ft.
ODECO	
115 stands DP	10,664.63
1 double DP	62.72
1 pup	21.73
6 heavyweight DP	182.22
16 6¾" drill collars	496.18

1 jar	16.22	
2 6¾" DC	62.33	
1 8½" stabilizer	3.95	
1 6¾" monel DC	29.80	
1 8½" stabilizer	4.08	
1 turbine	57.52	
1 bit	2.00	
	11,603.38	ft.
Total string length	12,127.38	
Difference in elevation *Neddrill/OR*	51.	
Drill string stretch Approx.	4.	
	12,182.	ft.
Ocean Ranger RT to middle pipe rams	328.	
Hang-off tool	8.	
Ocean Ranger drill string	11,603.	
	11,940.	ft.

The casing shoe is located at 12014 ft. Therefore the string was pulled approximately 75 ft. into the casing.

This, together with the presence of the hang-off tool indicates that the well was closed-in in an orderly and proper manner. In addition, examination of the top of the sheared pipe indicates that the shear rams functioned properly in cutting the pipe.

SETTING OF MECHANICAL/CEMENT PLUGS

The first of two bridge plugs was set by Schlumberger wireline at 11826 ft. at 0100 hrs., Friday, June 11/82. This plug was tested to 2500 psi for 5 minutes. At 1000 hrs. a bail or container of cement was sent down on wireline to provide a 15 ft. cement plug on top of the mechanical plug.

At this point R.M. Harvey was relieved by D.C. Strong.

The second plug was set at 1497 ft. at 1200 hrs. and also tested to 2500 psi. A cement slurry was then pumped down through the drill pipe to form a 150 ft. cement plug above the bridge plug. The drill pipe was then pulled up to 1200 ft., reverse circulated to clear any cement from the drill string and then pulled from the hole.

At 1845 hrs. the BOP stack was unlatched and retrieval operations commenced. At 2230 hrs. the BOP stack was out of the water and the tabs on posts, guidelines and the beacon holder were being cut off to facilitate the securing of the stack.

At 0100 hrs., June 12, 1982, installation of the support beams commenced. The skid frame was then assembled around the BOP stack, enabling the marine riser to be disconnected. The stack was then skidded into the T-slot between the two *Neddrill* BOP stacks for the trip back to St. John's.

At 0700 hrs. the corrosion cap was run down to the wellhead on drillpipe. The cap was landed at 0730 hrs. and the drillpipe disconnected.

At 0800 hrs. anchor handling commenced. The vessels *Boltentor* and *Nordertor* first retrieved anchors 6 and 7 which lay on either side of the *Ocean Ranger* wreckage, keeping tension on the anchor lines by pulling ahead as the lines were being reeled in on the windlasses. There was no visible indication that the *Ocean Ranger* wreckage was disturbed during this operation. The anchors on the starboard side were then retrieved. Examination of cables 6 and 7 showed some individual strand breakage.

By 1430 all the anchors were retrieved, the hydrophones retracted and the tautline pulled in. The vessel then departed for St. John's. On the way back to port, the stands of *Ocean Ranger* drill pipe were picked up, broken out and laid down.

The vessel arrived in St. John's at 0800 hrs., June 13, 1982. Mobil Oil was requested to store the sheared pipe and hang-off tool securely pending a decision from the *Ocean Ranger* Royal Commission regarding its disposition.

At no time did the *Ocean Ranger* wreckage appear to have been disturbed during this operation.

Robert M. Harvey
Derek C. Strong
Edward P. Lannon

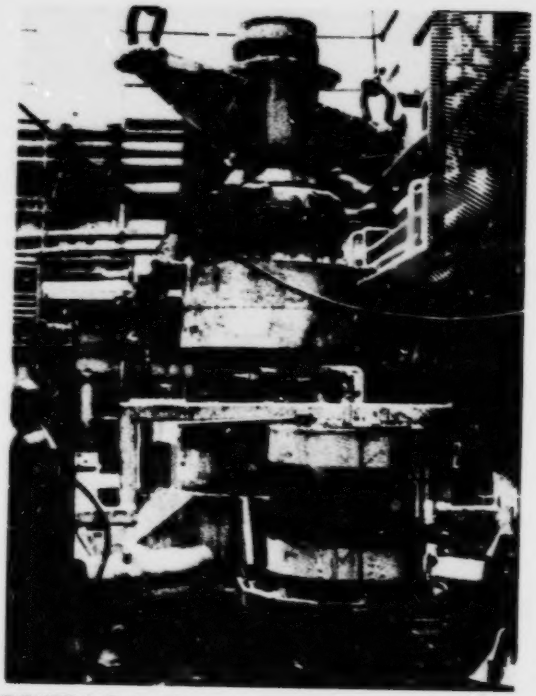


FIGURE 1 *Ocean Ranger* Lower Marine Riser Package

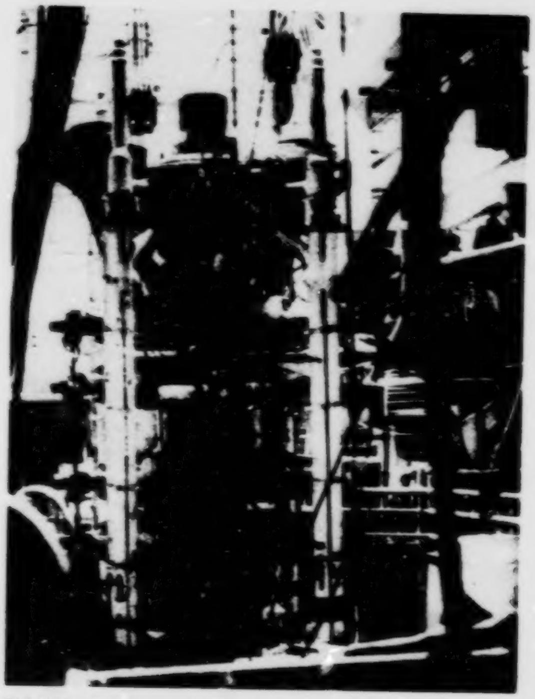


FIGURE 2 *Ocean Ranger* Blowout Preventer Stack (June, 1981)

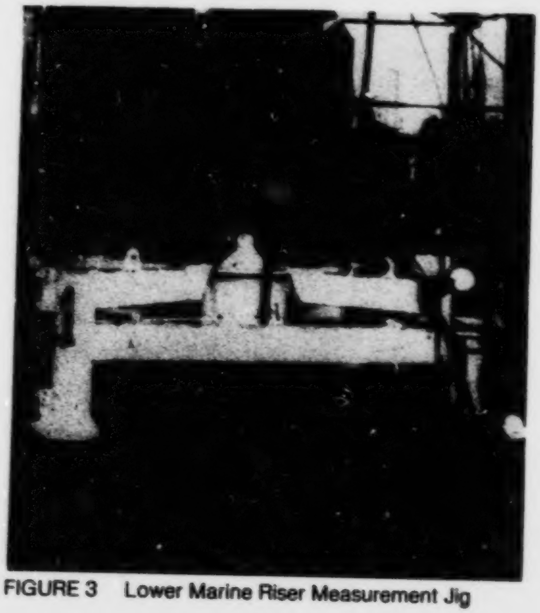


FIGURE 3 Lower Marine Riser Measurement Jig

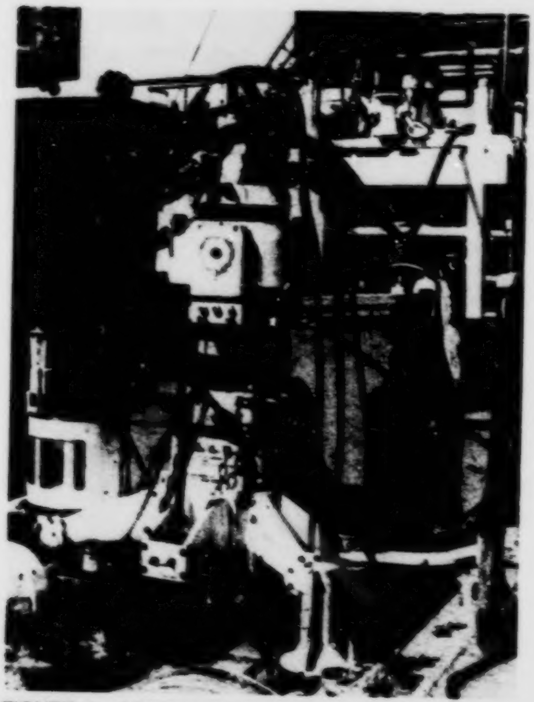


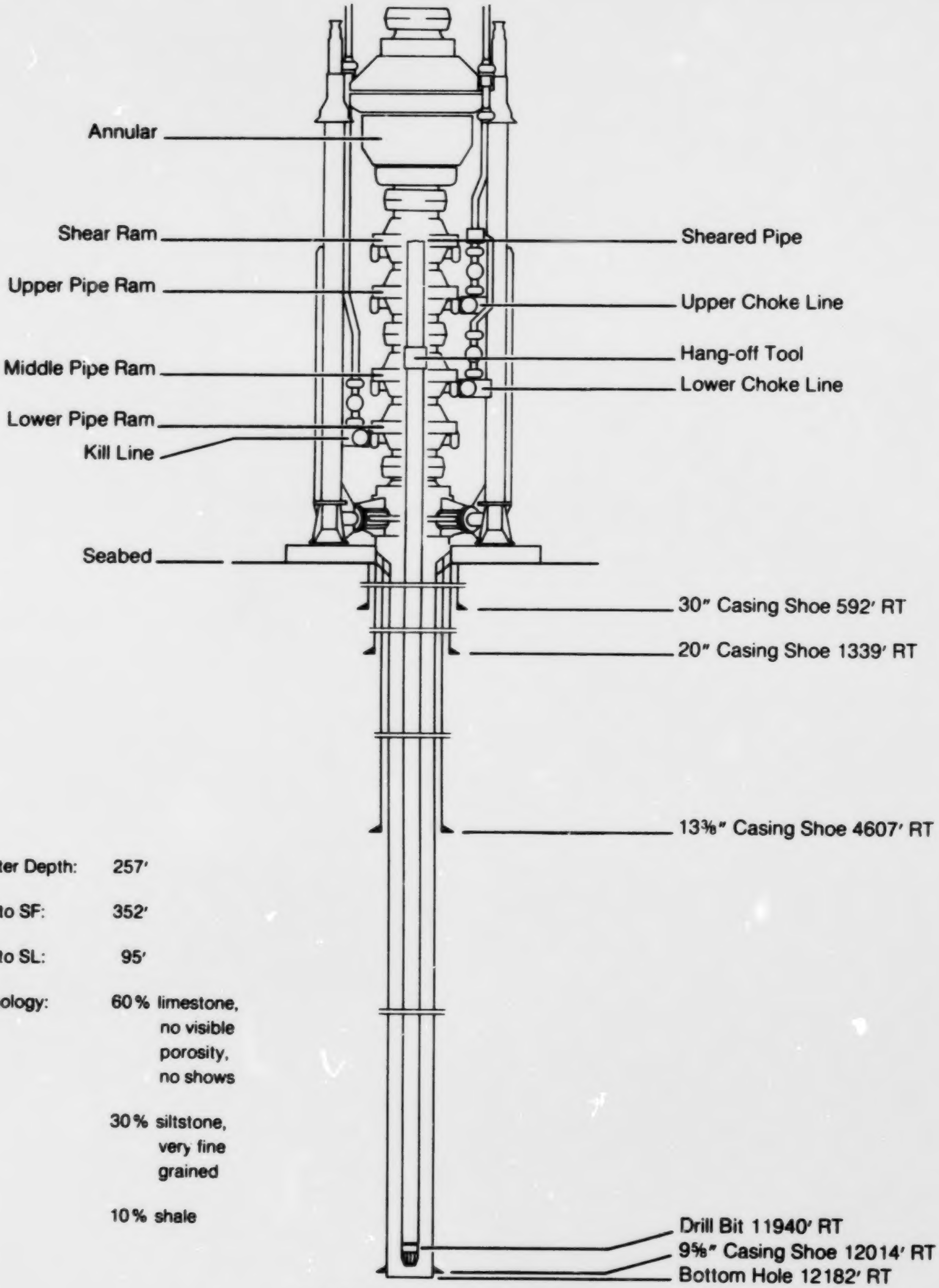
FIGURE 4 LMRP assembly by Mobil for re-entry to Hibernia J-34. Note: Only one control pod has been installed.

FIGURE 5 Drill fluid being pumped from the J-34 well.

FIGURE 6 Mill pulled from hole with sheared pipe wedged in its throat. Note top of hang-off tool.

FIGURE 7 Mill used to grind down the sheared end of the drill pipe.

FIGURE 8 Sheared pipe removed from mill.


Annular
Shear Ram
Upper Pipe Ram
Middle Pipe Ram
Lower Pipe Ram
Kill Line
Seabed
Sheared Pipe
Upper Choke Line
Hang-off Tool
Lower Choke Line
30″ Casing Shoe 592′ RT
20″ Casing Shoe 1339′ RT
13⅜″ Casing Shoe 4607′ RT
Drill Bit 11940′ RT
9⅝″ Casing Shoe 12014′ RT
Bottom Hole 12182′ RT

Water Depth: 257′

RT to SF: 352′

RT to SL: 95′

Lithology: 60% limestone, no visible porosity, no shows

30% siltstone, very fine grained

10% shale

FIGURE 9 Hibernia J-34 well diagram

FIGURE 10 *Ocean Ranger* hang-off tool. The large diameter steel bottom section is designed to rest on the pipe rams of the BOP stack.

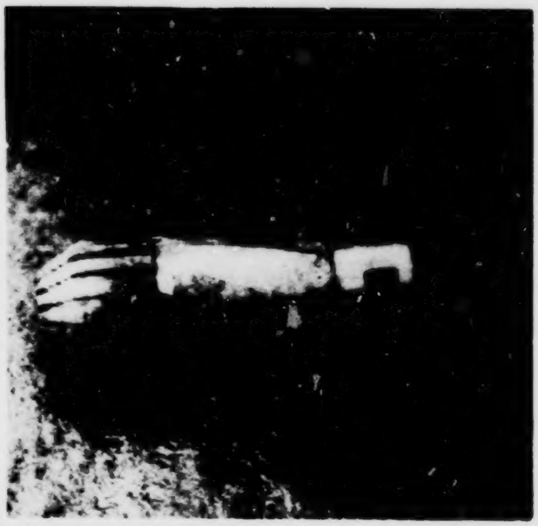


FIGURE 11 *Ocean Ranger* Drill Bit

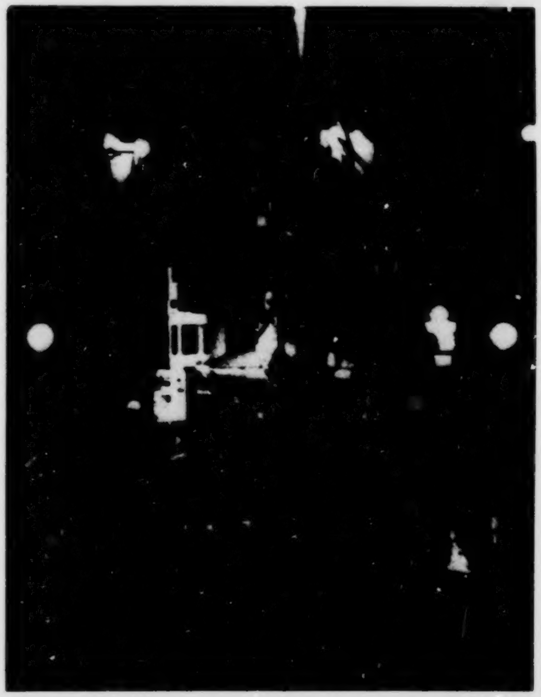


FIGURE 12 *Ocean Ranger* BOP stack in the *Neddrill 2* moonpool.

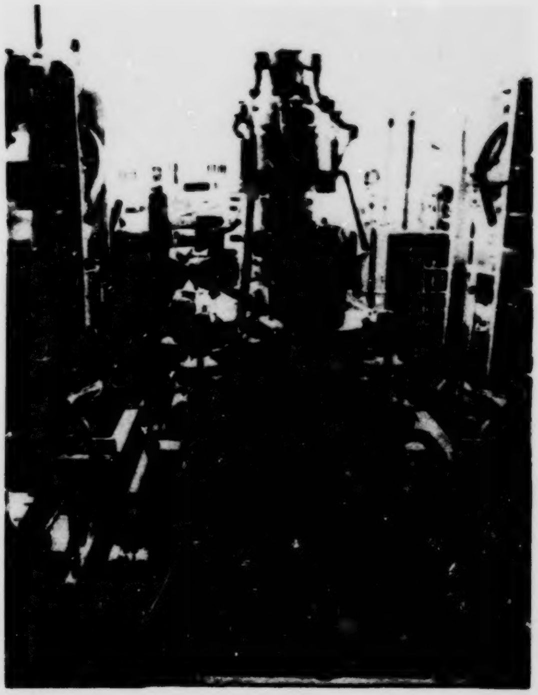


FIGURE 13 BOP stack pulled back.

Item F-2
Items Recovered During the Royal Commission's Dive Survey

1. 1 section of platform leg including porthole with glass broken out and deadlight cover attached.
2. 1 porthole with glass intact and deadlight cover attached.
3. 1 porthole with glass broken out and deadlight cover attached.
4. 2 horizontal instrument panel sections (less switches) from extreme left and right of ballast control panel.
5. Switches and lights for above panels.
6. 2 horizontal instrument panel sections from centre of control panel complete with switches.
7. 6 banks of solenoid-operated pneumatic valves; 18 manual control rods in place in solenoids.
8. 8 packages of books and documents retrieved from ballast control room.

Item F-3
Engineering Reports, A to I

Prepared by:

Aviation Safety Engineering Facility,
Aviation Safety Bureau
Transport Canada

REPORT A	**Portholes Examination**
REPORT B	**Porthole Glass Pressure Tests**
REPORT C	**Analysis of Solenoid Control Valves**
REPORT D	**Ballast Control Mimic Panel Analysis**
REPORT E	**Ballast Control Panel Light Bulb Analysis**
REPORT F	**Ballast Control Panel Tests**
REPORT G	**Ballast Control Electrical System & Overall Analysis**
REPORT H	**Pump Switch Failure Demonstration**
REPORT I	**Microswitch Failure Analysis**

[Editors note: Editorial changes have been made to these reports, with the author's approval, to assist in publication.]

REPORT "A"
ENGINEERING REPORT
EP 266/82
PORTHOLES EXAMINATION
8 September 1983

INTRODUCTION

1.1 On 15 February 1982 the mobile offshore drilling rig *Ocean Ranger* capsized and sank during a severe storm 180 miles off the coast of Newfoundland. All 84 men aboard were lost. The Royal Commission investigating the *Ocean Ranger* Marine Disaster requested the Aviation Safety Engineering (ASE) Facility, of the Aviation Safety Bureau, Transport Canada to assist in the investigation by conducting certain tests and analyses on three portholes forwarded to the ASE Facility under a covering letter dated 3 August 1982.

1.2 Specifically, it was requested that ASE try to determine:

a) the type of glass used in the portholes;
b) the uniform pressure required to burst the glass in the one good porthole received;
c) the direction of forces which caused the glass to burst in the other two portholes;
d) how the glass was removed in one of the portholes received;
e) whether the deadlights were open or closed when the glass burst;
f) the torque required to loosen the deadlight bolts;
g) other observations as pertinent to the porthole damage.

1.3 Further communications with the Royal Commission on 14 December 1982 more specifically identified the portholes received. The Ballast Control Room section of drawing number P-0403 was referred to, and a reference point B4, as indicated on the drawing, located the inboard aft porthole which was identified as porthole number 1. The portholes were subsequently numbered anticlockwise 1-4 when viewing the drawing. The portholes received were further identified as follows:

No. 1, inboard aft porthole, broken, containing fragments of glass. This porthole was removed to allow entry into the ballast control room during the diving survey;

No. 2, porthole not broken (to be used in burst test);

No. 4, porthole, one of two set in a "spectacle" insert plate. Broken, containing no glass fragments.

It was reported that the three portholes received had been recovered during the diving survey following the disaster.

EXAMINATION

2.1 The three portholes received are shown in Photo 1 numbered 1, 2 and 4. The deadlight bolts on portholes 1 and 4 were only "hand-tight" and were easily removed (no torque reading). The deadlight bolts on porthole No. 2 were "frozen" on their threads, likely due to salt-water immersion. When these bolts were "unfrozen", they were also determined to be hand-tight and subsequently moved freely. The force required to loosen the frozen bolts was not directly related to the actual clamping force on the deadlight. Photo 2 shows the three portholes with deadlights open.

2.2 An initial examination of each porthole as received was conducted. Pertinent measurements were taken and a brief description of each was compiled.

PORTHOLE NO. 1, PHOTOS 3 AND 4

The porthole glass was broken, leaving glass fragments in a continuous pattern around the porthole circumference. The glass fragments were held in place by the locking ring. The glass thickness was measured at different locations around the circumference and was found to average 14.95 mm (0.59 inches). The inside diameter of the glass locking ring was measured across three diameters at 120° to each other and found to be 459 mm (18.09 inches) in each direction, indicating no out-of-round. The outside diameter of the locking ring was similarly measured and found to be 476 mm (18.74 inches) in each direction. This measurement was also assumed to be approximately equal to the diameter of the porthole glass (after accounting for clearance to allow for glass expansion).

The inside surface of the deadlight was examined using an optical microscope. The inside surface displayed a golden-brown coloured tinge with a well distributed random pattern of corrosion pitting. The corrosion pitting was considered to be severe in comparison with the two other porthole deadlights. The comparative severity of the corrosive attack was post recovery in nature. Concentrated over one area on the inside surface, there was a fine distribution of reflective particles. The particles were lying on the surface, not embedded, and a sampling was taken for closer examination.

Energy dispersive x-ray analysis indicated the particles to be predominantly salt crystals, the origin of which is considered to be evaporated sea water. One of the particles collected, however, was analysed as glass. There did not appear to be any predominance of minute scratches on the inside surface of the deadlight, such as might be caused by broken glass impacting the surface.

PORTHOLE NO 2, PHOTOS 5 AND 6

The glass in porthole No. 2 was intact. No visible damage marks were observed. The glass thickness at various locations was measured and found to average 14.7 mm (0.58 inches). A straight edge placed on the glass surface showed it to be relatively flat but with a slight concave nature on the inboard side measuring 0.20 mm (0.008 inches) at the centre of the glass. The inside diameter of the locking ring was measured across three diameters at 120° to each other and found to be 460 mm (18.11 inches) in each direction, indicating no out-of-round. The outside diameter of the locking ring was similarly measured and found to be 476 mm (18.74 inches) in each direction. Optical examination of the inside surface of the deadlight revealed minor corrosion pitting caused by salt-water exposure.

PORTHOLE NO. 4, PHOTOS 7 AND 8

There was no glass in porthole No. 4. The rubber glass seal was in place in the seal groove of the glass support flange. The seal was broken at one location adjacent to the deadlight hinge, Photo 9, but none of the seal was missing. On the outboard edges of the glass support flange and porthole, numerous impact marks and gouges were observed, Photo 10. These marks were bright in colour and appeared to be randomly located around the full circumference of the porthole. The marks appeared to be the result of concentrated and repeated impacts. Testing showed that the orientation and severity of the impact marks could only have been made by blows from outside the porthole. They were bright in colour (indicating them to be recent in nature) and it was determined, most likely, that they occurred during removal of the porthole from the rig structure. The glass locking ring was still in place and the width of the groove which held the glass was measured. The groove width measured from the top of the seal was 14.5 mm (0.59 inches) and without the seal the groove measured 16 mm (0.63 inches). The inside diameter of the locking ring as measured across three diameters at 120° to each other, was 459 mm (18.07 inches) and the outside diameter was 476 mm (18.74 inches) in each direction indicating no out-of-round. As with the deadlight of porthole No. 2, the inside surface of the porthole No. 4 deadlight showed minor amounts of corrosion pitting caused by saltwater exposure. There did not appear to be any predominance of scratches on the inside surface of the deadlight such as may have been caused by broken glass impacting the surface.

2.3 Detailed examination of porthole No. 1 revealed that the glass remnants were sloped towards the inboard side of the porthole. Using a level and a dial indicator, it was possible to measure the slope of the glass on the outboard surface. The calculated slope angle of the glass surface was 2.3 degrees. The direction of slope on the glass indicates an inward force on the glass caused failure. The locking ring was removed from the porthole and the glass was removed, Photo 11. The rubber glass seal was found intact and in place in its groove. One distinctive characteristic of the glass fragments was the pattern of cracking, Photo 12. In all cases, the outboard surface of the glass had formed what could be described as a "shear lip". This cracking pattern is typical of a bending overload failure with the direction of force acting from the outboard to the inboard side of the glass.

2.4 Detailed examination of porthole No. 4 revealed a protruding "lip" of metal on the locking ring, Photo 13. This material lip was continuous around the circumference of the ring on the side adjacent to the glass. The ring was removed for closer examination. Photo 14 shows a polished and chemically etched cross section of the locking ring from porthole No. 4 illustrating the protruding lip. Examination of the material structure in the vicinity of the lip revealed a pattern of material flow indicating shear deformation of the ring at that point. A cross section of the ring was taken 180° opposite the section shown in Photo 14 for comparison. The magnitude of the shear deformation did not appear to differ by a measurable amount. This pattern of shear deformation and the continuous protruding lip around the full circumference of the ring, is an indication that glass failure occurred in an inboard direction as a result of high impact loading evenly distributed over the glass surface. A similar examination of the ring cross section from porthole No. 1 was done. There was no protruding lip found and no strong indication of shear deformation on the ring surface adjacent to the glass.

2.5 Metallurgical examination of the material microstructure of the locking rings revealed a narrow band of deformation slip lines (characterized by a crosshatch pattern) just below the ring surface which mates with the glass, Photo 15 and 16. The slip line pattern extended further below the surface in the ring from porthole No. 4 and was much more prevalent in the area of the protruding lip, Photo 17. Slip lines are formed as a result of deformation in the material and are characterized by a crosshatch pattern.

2.6 Energy dispersive x-ray analysis indicated the material of the porthole glass locking ring to be a copper-bronze casting alloy containing lead, tin and zinc as alloying elements. Brinell Hardness tests on the ring cross sections gave values of 40-45 Brinell Hardness Number (BHN, 500 kgm load) for both rings.

2.7 The granular pattern of failure of the glass from porthole No. 1 and the lack of any distinctive sharp splinters is typical of tempered glass failures. Examination of the glass did not reveal any laminations and it was concluded that the porthole glass used was tempered or "toughened" glass.

DISCUSSION

3.1 The metallurgical analysis of the locking rings indicates that the loads on the glass of porthole No. 4 were of higher magnitude and more of an impact nature than the loads on the glass of porthole No. 1. It is considered most probable that the glass in porthole No. 4 burst due to a dynamic surface ocean wave impact. On the other hand, the lack of any significant material deformation in the locking ring from porthole No. 1 suggests more of a static loading condition. Static pressure loads would be applied as a result of sinking to the sea floor if a pressure differential exists across the glass. This would require the deadlight to be closed and sealed, trapping an air pocket on the inboard side of the glass. The static pressure loads alone would not have been sufficient to burst the porthole glass. However, a concentrated blow by a sharp object might easily shatter tempered glass, particularly if it is already sustaining a pressure load. It is, therefore, considered likely that the glass received a blow from some object while it was submerged.

3.2 If glass particles had been observed imbedded on the inside surface of the deadlight from porthole No. 4, or if distinctive scratches were observed on this surface, a positive conclusion might have been drawn that the deadlight was closed when the glass burst under the dynamic loading conditions of the wave impact. Although not necessarily conclusive evidence, the lack of such witness marks does suggest that the porthole No. 4 deadlight was open at the time. Due to the more static loading conditions under which the glass burst in Porthole No. 1, similar witness marks would not be expected on the inner surface of this deadlight, even though it was concluded that this deadlight was closed at the time.

CONCLUSIONS

4.1 The type of glass used in the portholes was tempered or "toughened" glass.

4.2 The uniform pressure required to burst the glass in porthole No. 2 will be determined under separate testing, refer to ASE Report "B", (EP 90/83).

4.3 The glass in portholes No. 1 and No. 4 burst as a result of forces applied in an inboard direction. No more definitive direction of force in relation to the glass surface could be determined.

4.4 There were repeated impact marks on the outboard glass supporting flange of porthole No. 4, which contained no glass.

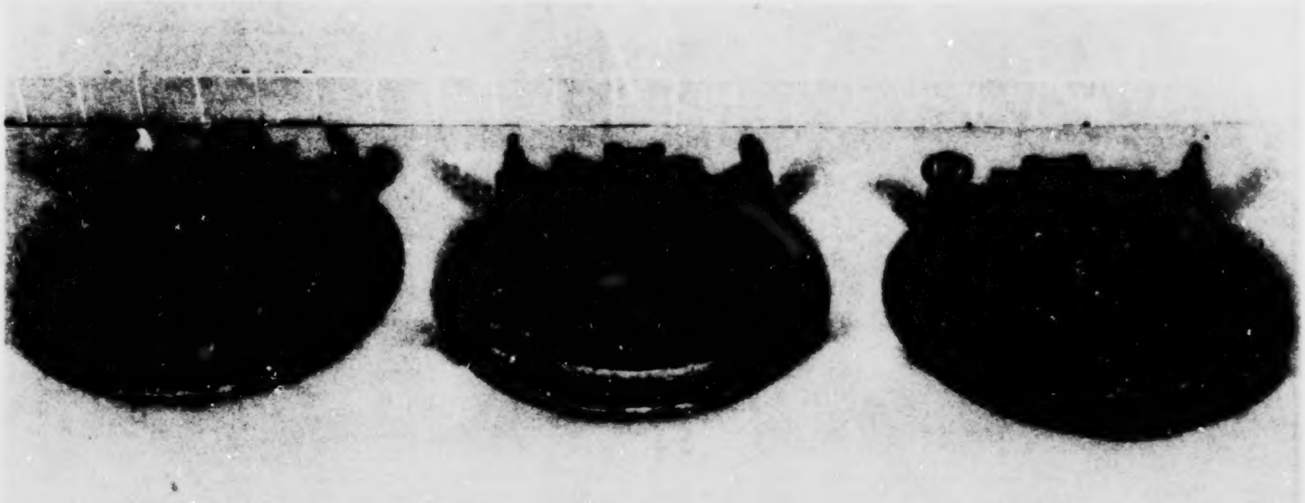
4.5 There was not sufficient evidence available on the porthole to enable conclusive determination of how the glass was removed.

4.6 Analysis indicates that the glass in porthole No. 1 probably failed under uniform pressure loads resulting from sinking to the sea floor, but assisted by a blow to the glass while submerged. It is also concluded that the deadlight was probably closed at the time of glass failure.

4.7 The glass in porthole No. 4 failed due to loads of an impact nature, likely resulting from surface waves. It was also determined that the deadlight was probably open at the time of failure.

4.8 The deadlight bolts on portholes 1, 2 and 4 were hand tight, and no significant break away torque values were recorded.

PHOTO 1 Portholes as received with deadlights closed. Identified by the numbers 1, 2 and 4.



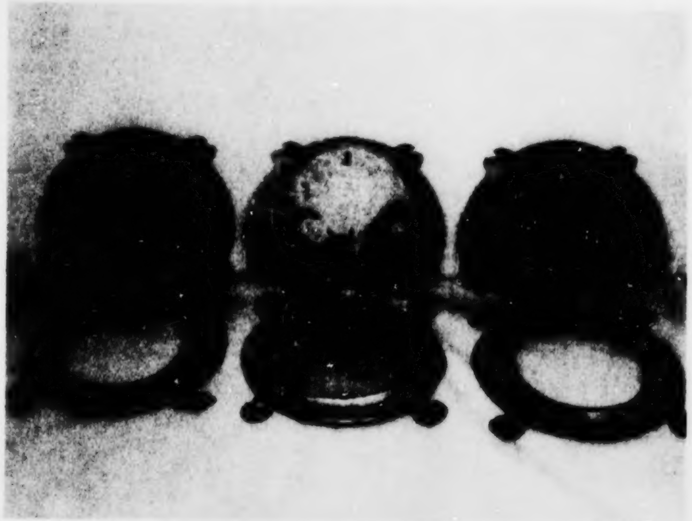


PHOTO 2 Portholes with deadlights open show the glass condition in each case.

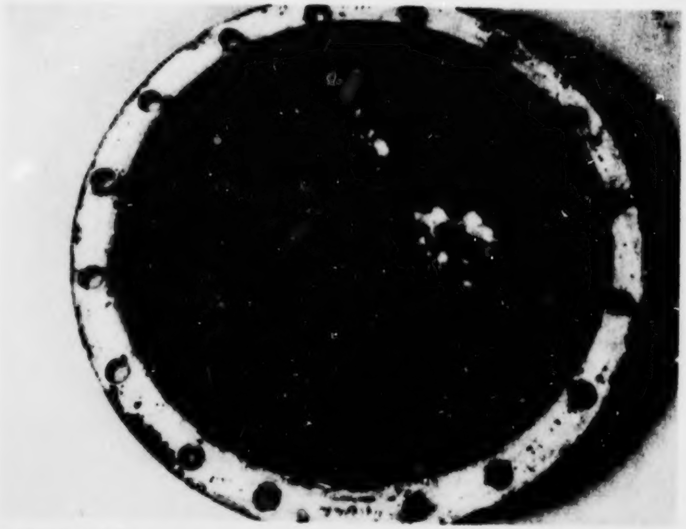


PHOTO 3 Porthole No. 1 with deadlight closed, view looking inboard.

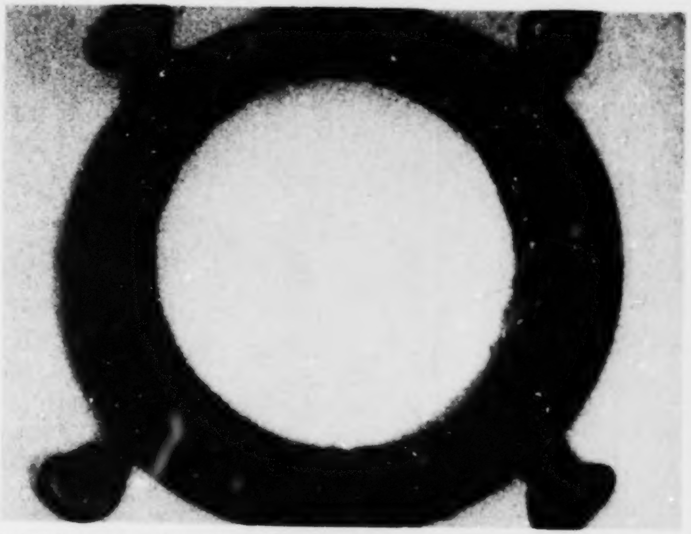


PHOTO 4 Porthole No. 1 with deadlight open, view looking outboard. Note glass fragments in continuous pattern around circumference.

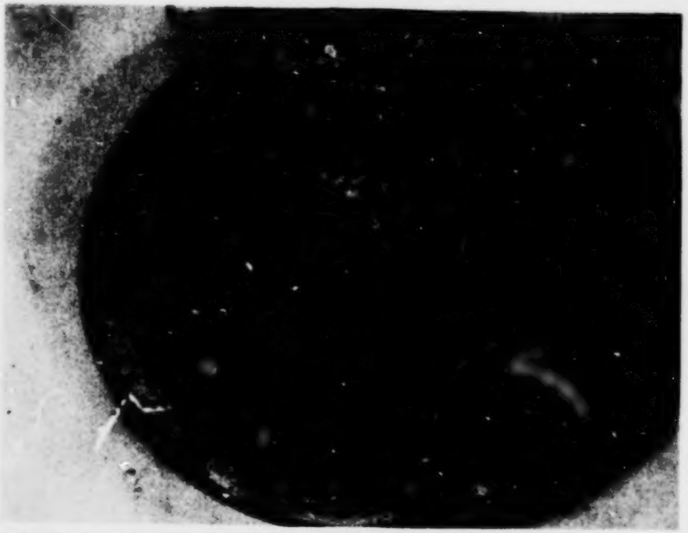


PHOTO 5 Porthole No. 2 with deadlight closed, view looking inboard.

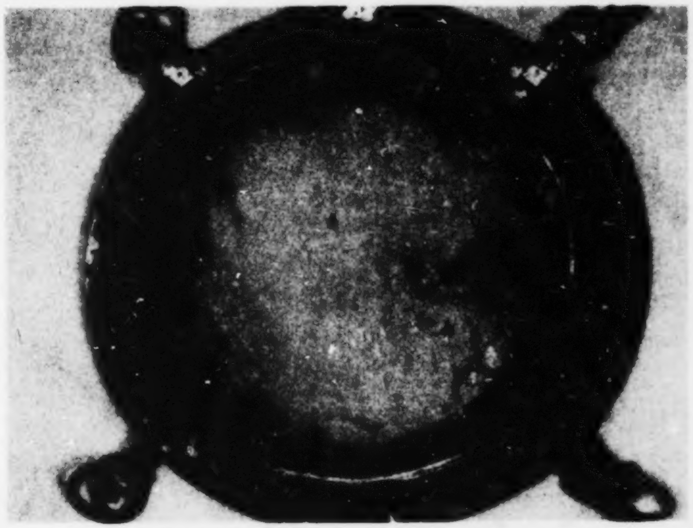


PHOTO 6 Porthole No. 2 with deadlight open, view looking outboard. Note glass intact.

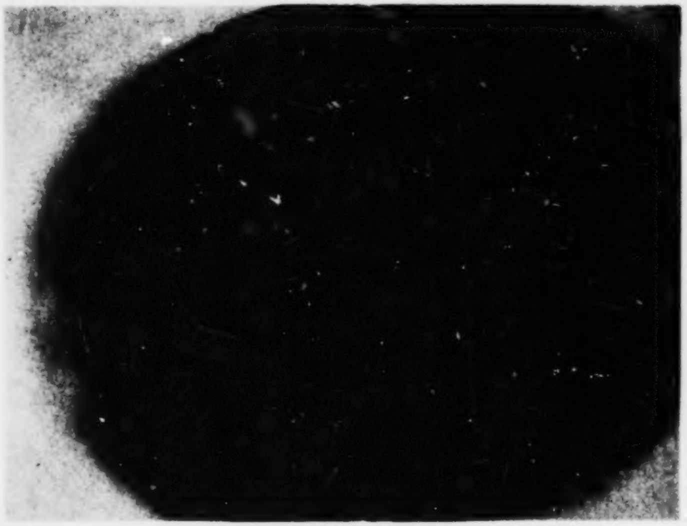


PHOTO 7 Porthole No. 4 with deadlight closed, view looking inboard.

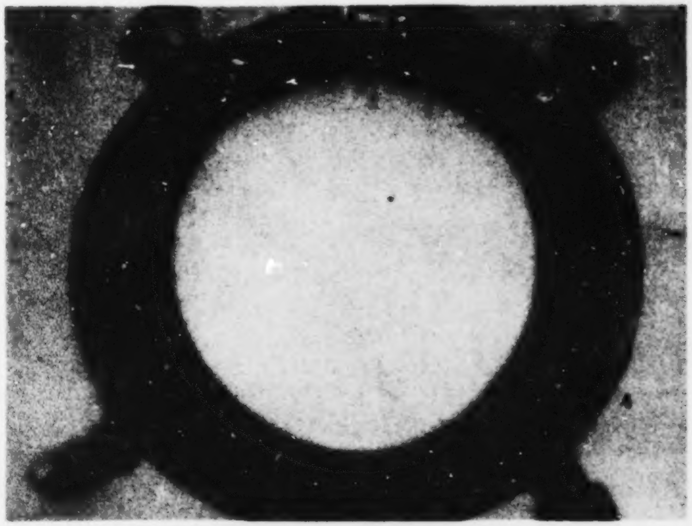


PHOTO 8 Porthole No. 4 with deadlight open, view looking outboard. Note glass completely removed, no fragments.

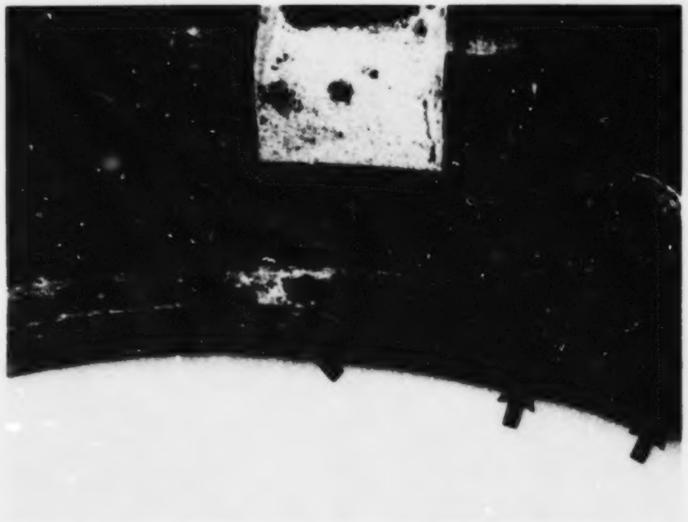


PHOTO 9 Porthole No. 4 showing broken seal (arrows) adjacent to the deadlight hinge. Also note profile of impact marks on outer edge of porthole (arrows) compare with photo 10.

PHOTO 10 Porthole No. 4 showing impact marks and gouges (arrows) on the outboard edges of the porthole.

PHOTO 11 Porthole No. 1 glass fragments after removal of the locking ring.

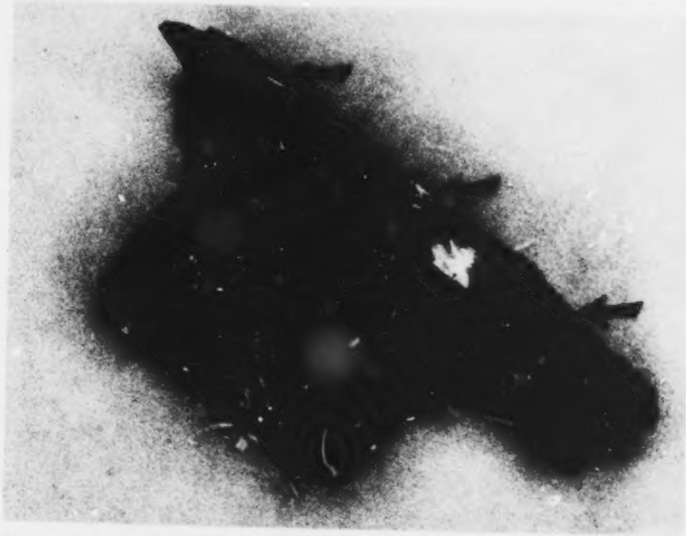


PHOTO 12 Glass fragment from porthole No. 1 displays a distinctive *shear lip* on the outboard side of the glass (arrows).

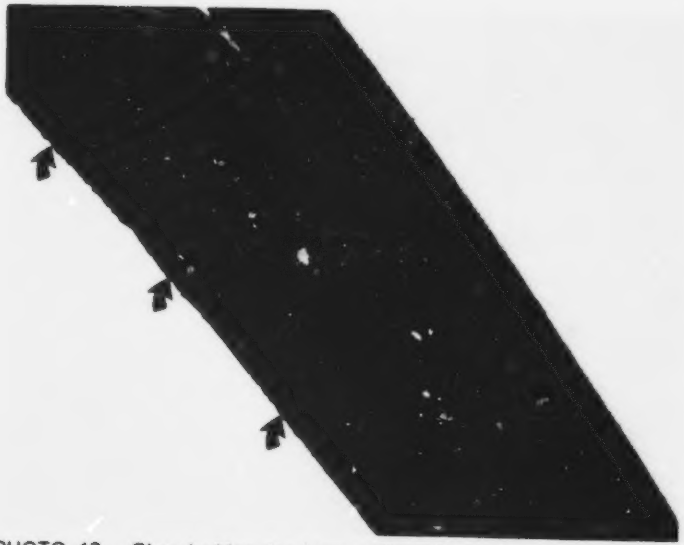


PHOTO 13 Glass locking ring from porthole No. 4 shows protruding lip of material along the inside edge (arrows).

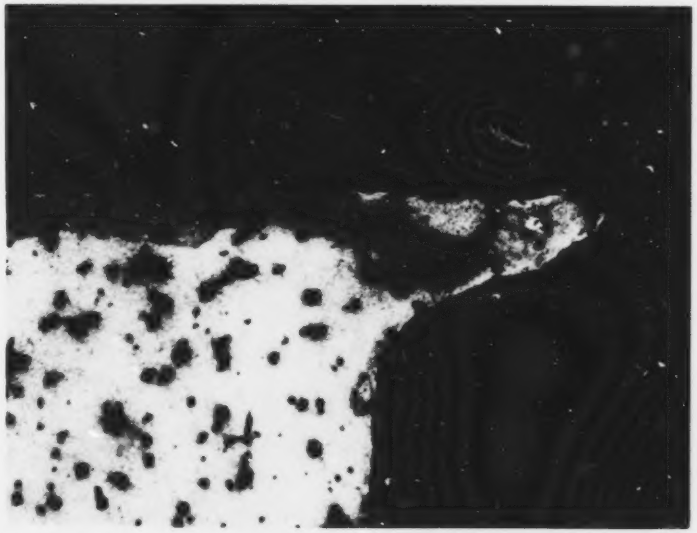


PHOTO 14 Cross section of locking ring shows protruding lip of material. Note the pattern of flow near the base of the lip indicating smearing deformation of the material.

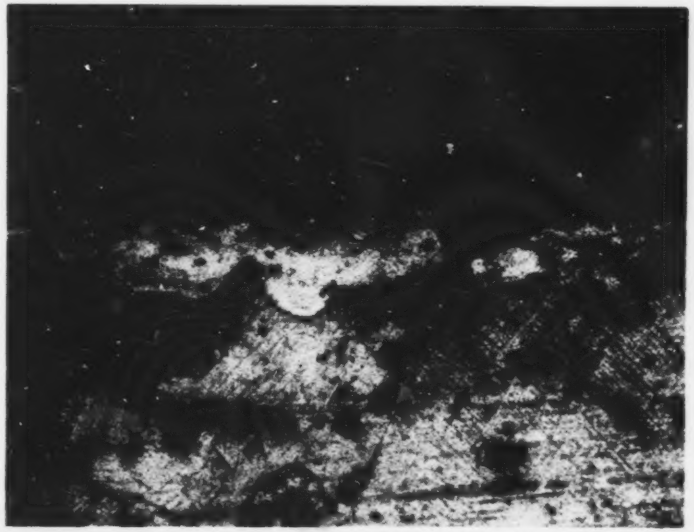


PHOTO 15 Deformation slip lines (crosshatch pattern) adjacent to the glass mating surface of porthole No. 4 locking ring.

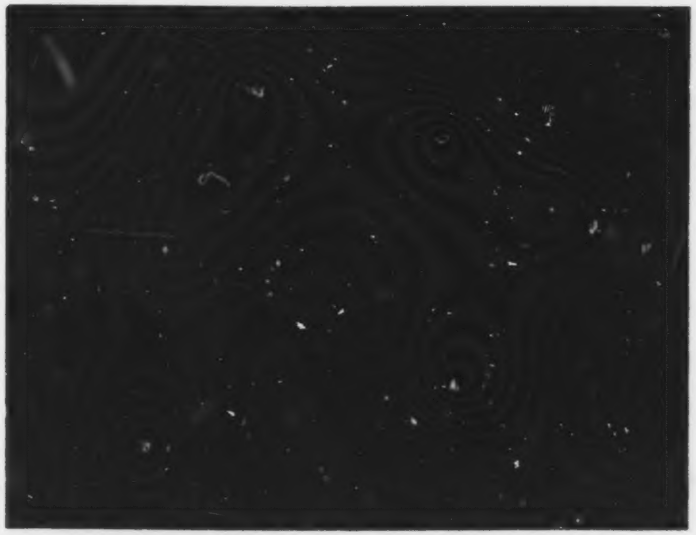


PHOTO 16 Deformation slip lines as in photo 15.

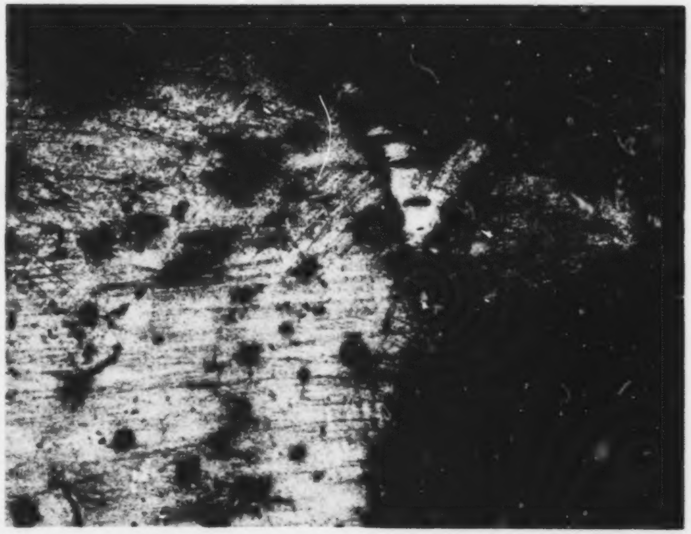


PHOTO 17 Porthole No. 4 locking ring cross section showing high concentration of deformation slip lines around the base of the protruding lip.

REPORT "B"
ENGINEERING REPORT
EP 90/83
PORTHOLE GLASS PRESSURE TESTS
8 September 1983

INTRODUCTION

1.1 The Royal Commission investigating the *Ocean Ranger* Marine Disaster requested the Aviation Safety Engineering (ASE) facility, of the Aviation Safety Bureau, Transport Canada to assist in the investigation by conducting certain tests and analyses on typical porthole glass and the No. 2 porthole retrieved from the rig's ballast control room. It was requested that ASE determine the pressure at which glass would fracture for comparison with standards and to provide burst pressure data for wave force analysis.

TEST DESCRIPTION

2.1 A test fixture depicted in Photos 1 and 2 was constructed. It consists of a heavy steel plate on a stand to which a porthole is bolted, and an air supply line complete with a small air tank intended to provide enough air to blow out the glass when it breaks in a manner similar to the water of a wave driving the fractured glass through the porthole. A gate valve, pressure gauge and pressure transducer controlled and monitored the test pressure.

2.2 A high speed film camera and two video cameras were used to film every test. The high speed camera was run at 2000 frames per second to record the fracture event and the distribution and speed of the glass fragments. One video camera monitored the pressure gauge while the other covered the test area, giving an overall view of the fixture and glass distribution.

2.3 The tests were controlled by a minicomputer which timed the start of the video cameras, valve opening, high speed camera start and the air exhaust at the end of the high speed film run. It also monitored and stored the output of the pressure transducer throughout the test. At the end of the test the data stored was printed out in graphical form. Figures 1 through 5 are direct computer printouts of these tests.

2.4 The porthole glass used in the rig's ballast control room was 1.5 centimeters thick and 48 centimeters in diameter. The No. 2 porthole glass retrieved from the *Ocean Ranger* was marked "Tempered Glass". The glass was presumed to be manufactured to Japanese Industrial Standard (JIS) F2410, of which a copy is attached.

2.5 Porthole glass from two different suppliers was obtained. It was considered that the glass was manufactured under a similar standard as JIS-F2410. Six sheets of glass from a Canadian manufacturer and three sheets of glass from a Japanese manufacturer were purchased. All nine sheets of glass had approximately the same dimensions and were all marked "Toughened" or "Tempered Glass".

2.6 Tempering or toughening of glass is traditionally a heat treatment process which heats the finished cut sheet of glass slowly to approximately 600 degrees Centigrade and then rapidly cools it with air. This process causes the surface part of the glass to be "frozen" in compression, greatly strengthening the glass sheet. However when the glass does fracture the internal stress will "explosively" drive thousands of fractures through the glass, creating the characteristic small, generally rectangular fragments of "toughened" glass.

2.7 All glass sheets, including the porthole No. 2 glass, were checked for evidence of tempering. The glass was placed between two sheets of optical polarizing plastic which would show the bifringe patterns characteristic of residual stress gradients in the glass. The bifringe patterns of three types of glass tested were markedly different as is evident from Photos 3, 4 and 5. This indicates that the cooling method used in the heat treatment processes were different. The *Ocean Ranger* glass was evidently cooled by a concentrated blast of air on both sides of the glass from a slightly off central location, while the Canadian and Japanese glass showed very little bifringe pattern and in a much more distributed way. These glass sheets were cooled with a more distributed air supply affecting more even cooling and less internal stress gradient. All glass tested fractured into the characteristic rectangular fragments, suggesting proper temper had been achieved.

2.8 Microscopic examination of the rig's No. 2 porthole glass revealed extensive pitting on both sides of the glass, with a density of approximately one pit per ten square centimeters and an average pit size of half a millimeter. Pitting typically reduces the fracture strength of glass, especially tempered glass. In order to determine the effects of pitting, a new sheet of both Japanese and Canadian glass was intentionally pitted in a manner similar to the *Ocean Ranger* glass. Their rupture strength was greatly reduced, as is evident from Table 1.

2.9 A total of twelve tests were performed on the ten sheets of glass tested. The results of the six most significant tests are listed in Table 1. One of these tests was a static pressure test to determine the extent of glass deformation (bulging) as a function of pressure. The deformation was measured directly with a lever arm over the glass and a displacement indicator. It was determined that at a pressure of 96 psi (6.8 kg/cm^2) the glass bulged 7.5 millimeters; causing angular rotation of the glass at the edge of the locking ring of approximately eight degress creating a total force of 120 tons or one ton per centimeter of locking ring.

2.10 The other five tests listed in Table 1 were semi-dynamic, i.e. the air pressure was allowed to rise as fast as the equipment allowed. The time required to reach rupture pressure was largely a function of glass strength and leakage around the glass, and could not be controlled without interfering with the typical glass mounting. All results of these tests are shown in Table 1 and graphs 1 to 5.

2.11 After testing the rigs's No. 2 porthole to bursting, the porthole locking ring was subjected to a metallurgical analysis, the results of which are attached.

CONCLUSIONS

3.1 The Canadian glass when new and undamaged failed just above the Japanese Industrial Standard F2410 proof pressure of 7 kg/cm^2 (99 psi). All other glass failed below this standard.

3.2 Surface pitting greatly reduced the rupture strength of the glass.

3.3 The *Ocean Ranger* porthole No. 2 glass was tempered in a different manner than all other glass tested.

3.4 Elastic deformation of the glass prior to rupture was found to be 7.5 millimeter bulge at 7 kg/cm^2.

3.5 The *Ocean Ranger* No. 2 porthole glass failed at a pressure of 4.8 kg/cm^2 (68 psi) causing deformation to the locking ring very similar to that found on the No. 4 porthole locking ring.

Department of Transport
Aviation Safety Engineering Laboratory
International Request for Technical Analysis

REQUIREMENTS

The No. 2 porthole from the *Ocean Ranger* Oil Rig was pressure tested as documented in ASE Report "B", (EP 90/83). Following testing, the glass retaining ring was removed. It is requested of the Materials Analysis Section (ASE/MAT) that the retaining ring be analysed metallurgically for evidence of material deformation and comparison made with previous metallurgical analyses made of the retaining rings from portholes No. 1 and 4, refer to ASE Report "A", (EP 266/82).

2 August, 1983 M. Vermij

FINDINGS

1. Close examination of the glass retaining ring from porthole No. 2 was carried out in-situ prior to pressure testing. There was no indication of any material lip observed on the ring. The No. 2 porthole is shown mounted on the test rig in Photo 6 following the pressure test to glass failure. The glass retaining ring was removed, brushed clean and examined optically. A continuous "lip" of material was observed around the full circumference of the ring on the side adjacent to the glass, see Photos 7 and 8. This material lip was very similar in nature to the protruding material lip observed on the glass retaining ring from porthole No. 4, see Photo 9.

2. The No. 2 porthole glass retaining ring was sectioned in the transverse direction and mounted for metallurgical examination. Photo 10 shows the ring in cross section and illustrates the protruding lip of material, which is generally similar in nature to the cross sectional view of the material lip in the ring for porthole No. 4, Photo 11. The effect of the material deformation is revealed by the pattern of material flow in the vicinity of the lip, also generally similar in the two rings being compared.

3. Energy dispersive x-ray analysis indicated the material of the No. 2 porthole glass retaining ring to be a copper-bronze casting alloy containing lead, tin and zinc as alloying elements. Brinell Hardness testing on the ring cross sections gave values within the range of 40-45 Brinell Hardness Number (BHN, 500 kgm load, 10 mm ball) which has previously been measured for the rings from portholes 1 and 4. Material and hardness values compared favourably for all three rings tested (Portholes 1, 2 and 4).

4. The chemical etching of the ring cross section from porthole No. 2 revealed only slight deformation slip lines formed as a result of material deformation. The degree of this deformation pattern was much less than observed in the cross section from porthole No. 4 and more similar in degree to the deformation patterns observed in the ring cross section from porthole No. 1.

5. From results of the No. 2 porthole pressure test it was shown that the test was conducted at a pressure rate of approximately 27 psi/sec, with glass rupture occurring at about 2.5 seconds. Under these conditions the test is considered to be essentially dynamic in nature, although not with the same dynamic impact loading believed to have been experienced by the glass of porthole No. 4, which was concluded to have failed under wave impact conditions. The similarities of the deformation lip on the retaining rings from portholes No. 2 and No. 4 and lack of deformation lip on the ring from porthole No. 1 (which failed under more static pressure conditions) is considered to indicate that the deformation lip on the glass retaining ring is caused by dynamic loading.

6. The relative differences in the degree of deformation slip line patterns of the retaining rings from portholes No. 1, No. 2 and No. 4 would appear to be a function of the nature of loading on the porthole glass. The porthole No. 4 retaining ring shows the greatest degree of slip line patterns and is also the one considered to have experienced the greatest degree of impact loading.

31 August, 1983 J.W. Hutchinson

TEST NUMBER	TEST RESULT REFERENCE	GLASS ORIGIN	CONDITION	PRESSURE TO FAILURE		TIME TO FAILURE
				kg/cm2	PSI	(SEC)
1		Japan (new)	clean	6.8	96	Static
2	6	Canada (new)	clean	7.4	105	5.7
3	11	Japan (new)	clean	6.8	96	7.0
4	7	Ocean Ranger	pitted	4.8	68	2.9
5	8	Canada (new)	pitted	5.6	79	3.4
6	10	Japan (new)	pitted	3.6	51	6.6

PRESSURE TEST RESULTS

TABLE 1

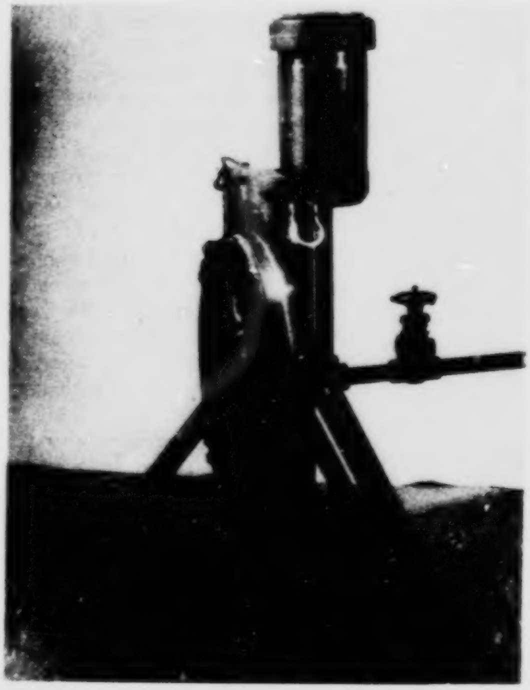


PHOTO 1 Side view of porthole glass test fixture.

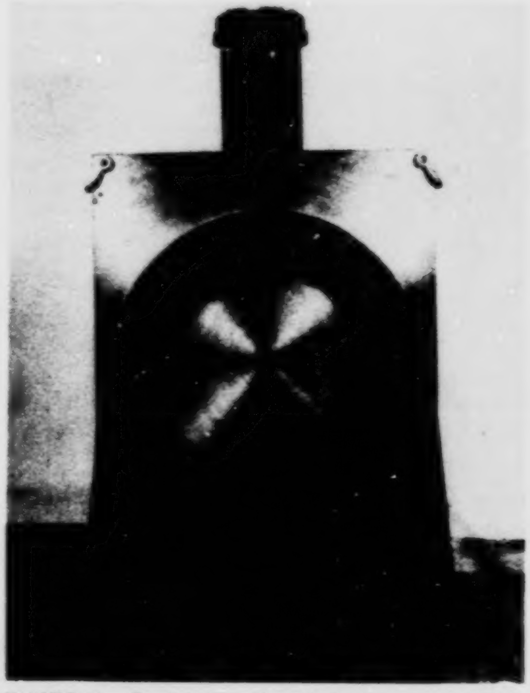


PHOTO 2 Frontal view of porthole glass test fixture.

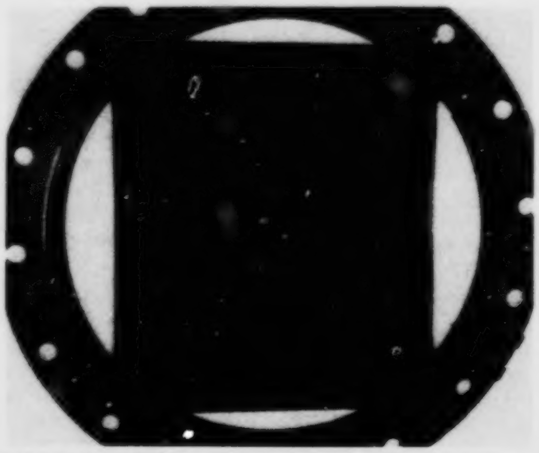


PHOTO 3 Bifringe pattern of *Ocean Ranger* #2 porthole glass, showing strong stress gradients.

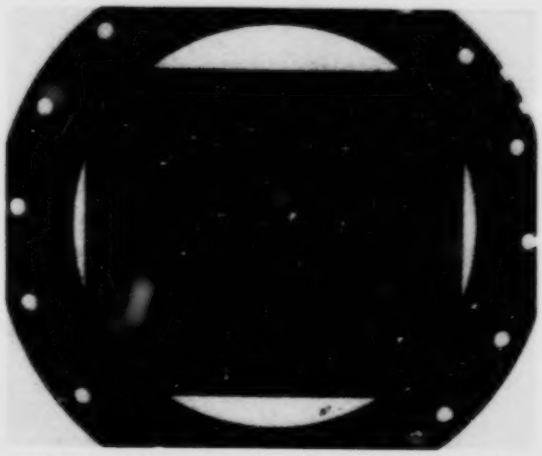


PHOTO 4 Bifringe pattern of Japanese glass (new) showing little stress gradients.

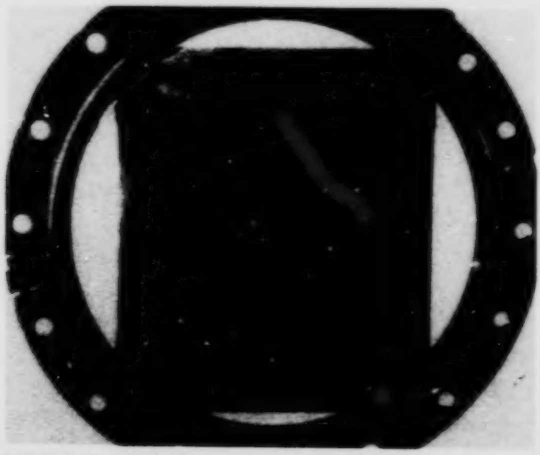


PHOTO 5 Bifringe pattern of Canadian glass (new) showing weak stress gradient patterns.

UDC 629.12.011.83 : 666.181

JAPANESE INDUSTRIAL STANDARD JIS

Tempered Glasses for Ships' Side Scuttles

F 2410-1955

1. Scope

1.1 This standard covers the tempered glass for ships' side scuttles (hereinafter referred to as the "tempered glass").

2. Class

2.1 Tempered glass shall be classified into the following two classes:

(1) Transparent tampered glass
(2) Ground tampered glass

3. Dimensions and Dimensional Tolerance

3.1 Dimensions of tempered glass shall be in accordance with Table 1.

Table 1

Unit: mm

Nominal diameter	Dimensions of glass	
	Diameter	Thickness
200	212	10 12
250	262	
300	312	10 12
350	362	15
400	412	

3.2 Dimensional tolerances of tempered glass shall be in accordance with Table 2.

Table 2

Unit: mm

Diameter	Tolerance	Thickness	Tolerance
212	± 1.0	10	± 1.0
262		12	
312		15	
362			
412			

4. Quality

4.1 In addition to the quality of tempered glass specified in Table 3, its characteristic shall fulfil the following requirements, namely, the clearance test, impact test and pressure test specified in 5.3, 5.4 and 5.5 respectively.

Table 3

Kinds of defect	Specifications for quality
Bubbles, stones, knots, striates and reams	In accordance with the specification for the standard product of 32'' × 24'' or less size given in Table 4 of JIS R 3202 Polished Plate Glass.
Spots, cloudings, and scratches	No remarkable interference for practical purpose.
Grizzles	Not to have
Edge chippings	Within 3 mm towards inside from the circumference
Overall appearance	No permissible defects shall be concentrated
Ground surface of tempered glass	No part left on the ground surface through which clearly seen a perspective image

5. Method of Test

5.1 Measuring Method of Dimensions The thickness of the tempered glass shall be measured by a micrometer with an accuracy up to 1/100 mm, and the thickness shall be determined by counting fractions over 1/2 as one and disregarding the rest.

5.2 Appearance The visual inspection of the tempered glass shall be performed by naked eyes at a distance of approximately 50 cm from the front face of the sample.

5.3 Clearance Test

(1) **Supporting Method of Sample** The sample shall be set on the surface plate, as shown in Fig. 1, so as to make a concentric circle with the inside circle of the surface plate. Further, a weight of approximately 5 kg shall be loaded on the central part of the sample

(2) **Surface Plate** The surface plate having a hole of 12 mm less than the diameter of the sample shall be used as shown in Table 4.

Table 4

Unit: mm

Diameter of sample (A)	Diameter of inside circle (B)
212	200
262	250
312	300
362	350
412	400

(3) **Measuring Method** The clearance between the circumference of the sample and its surface plate shall be measured by a clearance gauge choosing any point which equally divides the circumference into three parts.

(4) **Condition of Acceptance** When the mean value of the measurement at the three points falls within 0.5 mm, the products shall be accepted.

5.4 Impact Test

(1) **Supporting Method of Sample** The sample shall be so supported on the frame of hardwood shown in Fig. 2 that the sample will make a horizontal at the time of impact. In case of testing the opaque tempered glass, the ground surface shall be laid downwards.

(2) **Falling Body** A good finished steel ball of 225±5 g in weight and 38 mm in diameter shall be used.

(3) **Condition of Impulse** The steel ball at rest shall be dropped on the central part of the sample without giving any force. In this case the height shall be in accordance with Table 5 and impulse acted on the glass surface is limited just for once, and the testing shall be performed at a normal temperature.

Table 5[1]

Thickness of sample (mm)	Falling height of steel ball (m)
10	2.5
12	
15	3.0

Note [1] The above table provides only for the transparent tempered glass. For the ground tempered glass, these shall be determined by the agreement between the purchaser and the manufacturer.

(4) **Condition of Acceptance** Being free from cracks and fractures, the glasses shall be accepted.

5.5 Pressure Test

(1) **Supporting Method of Sample** Samples shall be exactly fitted to a water pressure testing device as shown in Fig. 3.

(2) **Condition of Water Pressure** The samples shall be tested by applying the pressure, according to each diameter and thickness of glass, specified in Table 6.

Table 6[1]

Unit: kg/cm²

Thickness of sample (mm) \ Diameter of sample (mm)	212	262	312	362	412
10	9	6	5	4	3
12	12	9	7	6	5
15	—	14	11	9	7

Note [1] The above table provides only for the transparent tempered glass. For the ground tempered glass, these shall be determined by the agreement between the purchaser and the manufacturer.

(3) **Condition of Acceptance** The samples to withstand the pressure specified in Table 6 shall be accepted.

6. Inspection

6.1 The appearance and dimensions should be, as a rule, inspected on each product.

6.2 Sampling method to be used in 5.3~5.5 shall be conducted by rational sampling method upon agreement of the parties concerned.

6.3 Being inspected for appearance, dimensions and characteristics of the sample, it shall be determined to accept or not.

7. Marking

7.1 Every plate of tempered glass shall be plainly and indelibly marked with the indication of tempered glass, manufacturer's name or mark.

8. Designation

8.1 The tempered glass shall be designated in order of the class and dimensions

Example: Class of transparent tempered glass, dimensions of 212 mm in diameter and 10 mm in thickness shall be expressed by Transparent D 212×10.

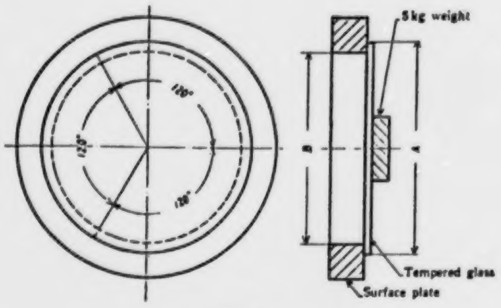


Fig. 1

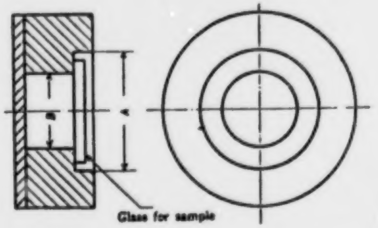


Fig. 2

Unit: mm

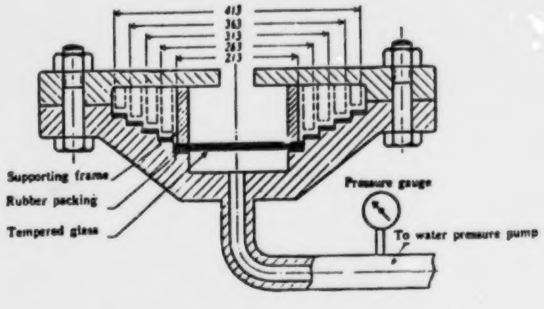


Fig. 3

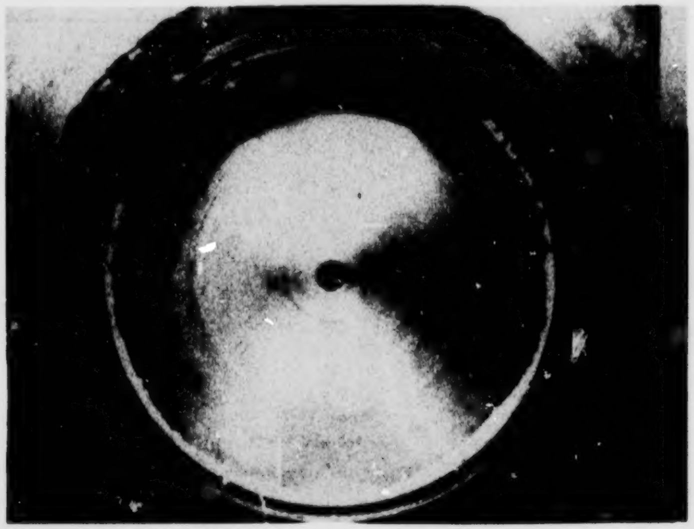


PHOTO 6 Porthole No. 2 following testing mounted on the test rig. Glass retaining ring in place.

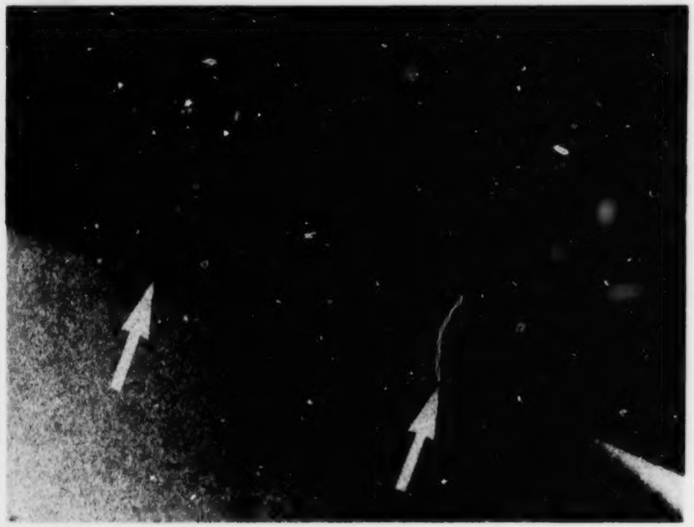


PHOTO 7 Glass retaining ring removed from porthole No. 2 shows protruding lip of deformed material (arrows).

PHOTO 8 Close-up view of the material lip (arrows).

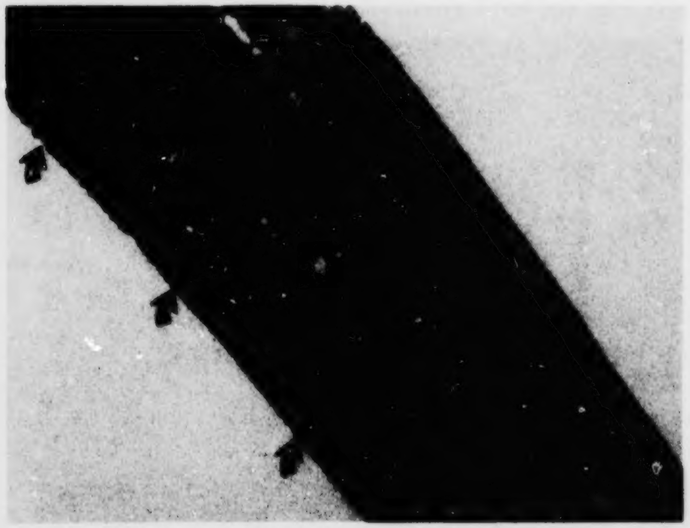


PHOTO 9 Glass retaining ring from porthole No. 4 shows similar protruding material lip (arrows).

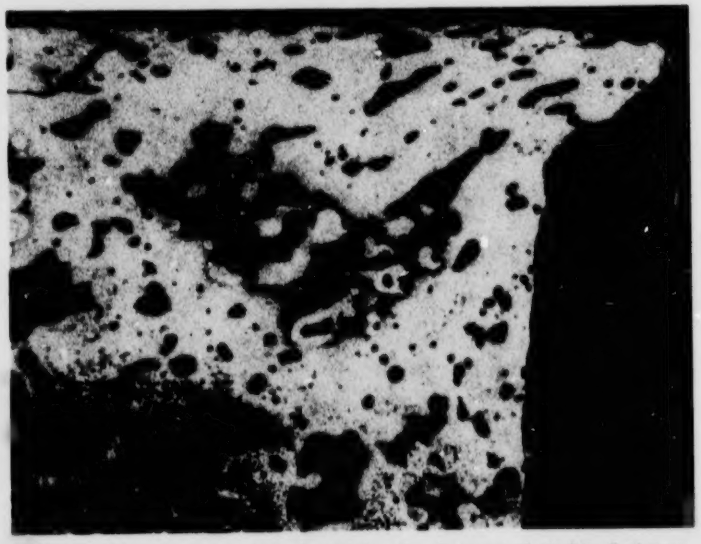


PHOTO 10 Cross section of retaining ring from porthole No. 2 shows distinct protruding lip. Note the pattern of flow at the lip indicating smearing deformation of the material.

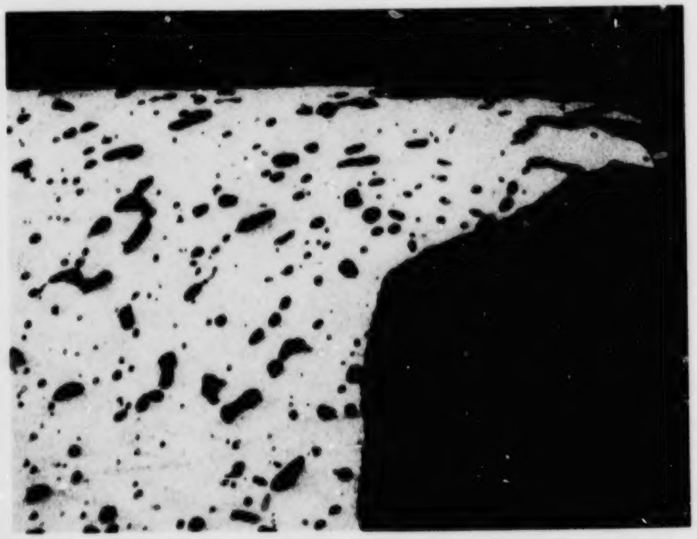
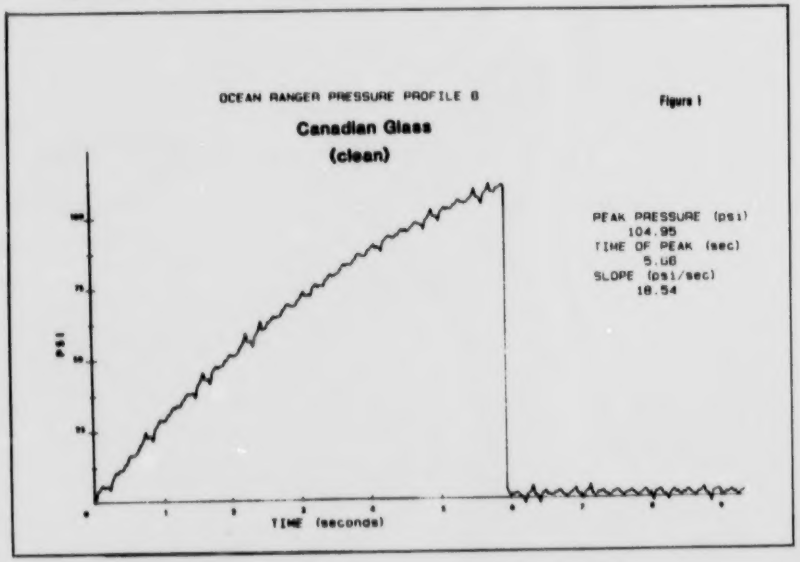


PHOTO 11 Cross section of retaining ring from porthole No. 4 shows similar protruding lip.

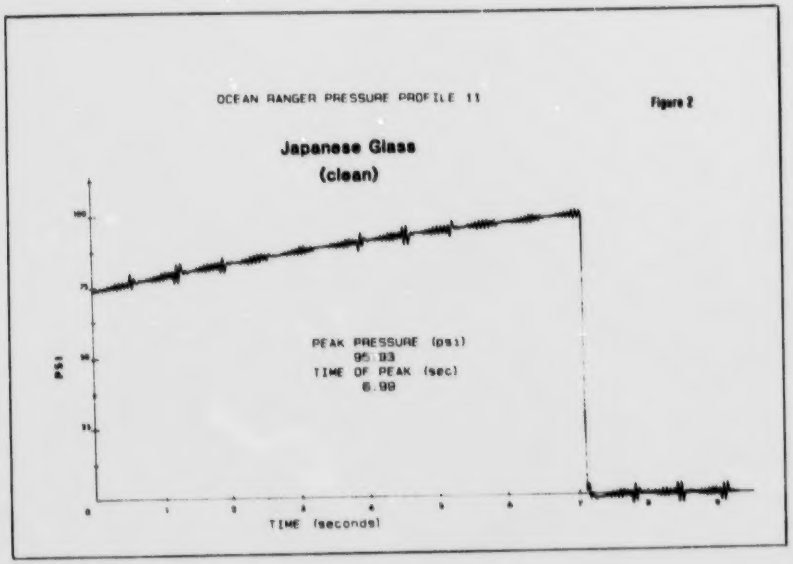


OCEAN RANGER PRESSURE PROFILE 8

Figure 1

Canadian Glass
(clean)

PEAK PRESSURE (psi)
104.95
TIME OF PEAK (sec)
5.88
SLOPE (psi/sec)
18.54



OCEAN RANGER PRESSURE PROFILE 11

Figure 2

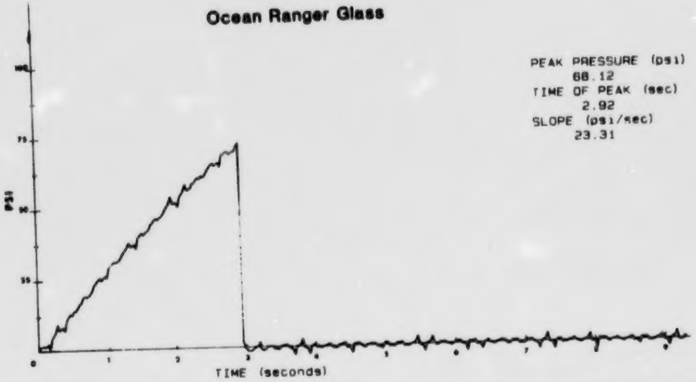
Japanese Glass
(clean)

PEAK PRESSURE (psi)
95.93
TIME OF PEAK (sec)
6.98

OCEAN RANGER PRESSURE PROFILE 7

Figure 3

Ocean Ranger Glass

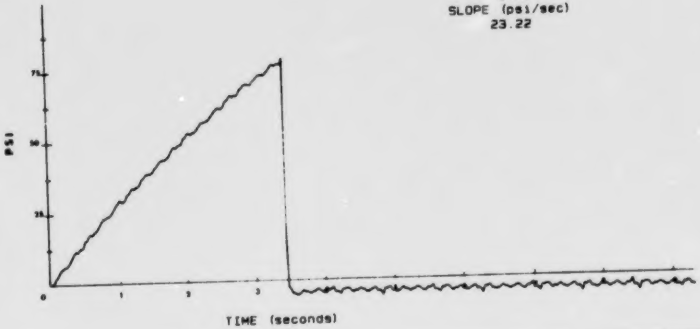


PEAK PRESSURE (psi)
68.12
TIME OF PEAK (sec)
2.92
SLOPE (psi/sec)
23.31

OCEAN RANGER PRESSURE PROFILE 8

Figure 4

Canadian Glass
(pitted)

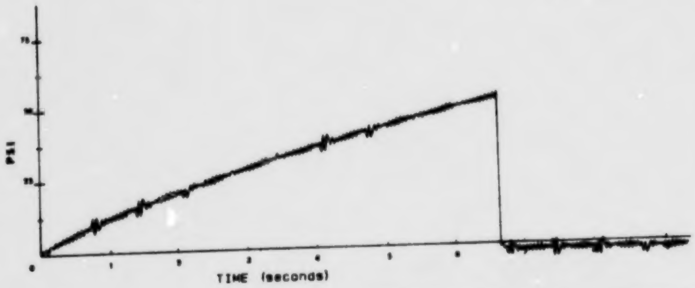


PEAK PRESSURE (psi)
78.98
TIME OF PEAK (sec)
3.40
SLOPE (psi/sec)
23.22

OCEAN RANGER PRESSURE PROFILE 10

Figure 5

Japanese Glass
(pitted)



PEAK PRESSURE (psi)
50.98
TIME OF PEAK (sec)
6.50
SLOPE (psi/sec)
7.74

REPORT "C"
ENGINEERING REPORT EP 265/82
ANALYSIS OF SOLENOID CONTROL VALVES
8 September 1983

INTRODUCTION

1.1 The Royal Commission investigating the *Ocean Ranger* Marine Disaster requested the Aviation Safety Engineering (ASE) Facility, of the Aviation Safety Bureau, Transport Canada to assist in the investigation by conducting certain tests and analyses on four banks of 11 solenoid control valves and two banks of 10 solenoid control valves which were removed, during underwater salvage efforts, from the *Ocean Ranger's* ballast control room. These 64 solenoid control valves were forwarded to the ASE Facility under covering letters dated 29 July 1982 and 3 August 1982.

1.2 It was specifically requested that ASE try to determine:

a) evidence of manual operation of the control valves;
b) whether rubber plugs not found on the valves had been pushed inside the valve solenoid housing;
c) which valves were in the activated and which were in the non-activated position;
d) material transfer evidence and/or indentations on the valve solenoid plungers indicative of manual operation;
e) the nature of any debris found inside the valves;
f) the possible effect of salt-water immersion on the solenoid valves;
g) the extent of air leakage from the valves when submitted to the normal operating air pressure of 90 psi;
h) whether the valves functioned normally when electrically activated;
i) other relevant observations.

EXAMINATION AND ANALYSIS

2.1 The 64 solenoid control valves received were identified as SMC model VS4130, 4-way solenoid valve of spool type, port size 3/8" with standard size piping, manufactured by SMC, Shoketsu Kinzoku Kogyo Co., Ltd. This type of valve has a single spring return mechanism and is normally operated with 90 psi air, and a 115 volts AC supply. The six solenoid control valve banks, as received, were located underneath the ballast control room mimic panel and are shown in Photos 1-3. A layout of the relative positions of all 64 valves in the 6 banks is shown in Figure 1. When activated, the solenoid valves control the opening and closing of the tank butterfly valves; thereby governing the relative distribution of air and water in the various tanks within the pontoons and hence, the relative flotation characteristics of the mobile drilling rig.

2.2 Thirty-two solenoid valves were used for the port side pontoons, and thirty-two for the starboard pontoons. Two different designation systems were found to identify the valves, as is evidence from Photo 4:

a) a brass plate with lettering P1, P2, . . . P32 for the port side S1, S2, . . . S32 for the starboard side;
b) a red plastic label 'Dymo' tape with white lettering SOV-1 to SOV-32 for valves P1 to P32 inclusive SOV-33 to SOV-64 for valves S1 to S32 inclusive.

Table 1 lists which butterfly valve each solenoid valve controlled, as per the Royal Commission *Ocean Ranger* Exhibit 74A drawing 061.

2.3 The capability for manual activation of the solenoid control valves is provided for emergencies in the form of a brass plug and actuator rod. Photo 5 illustrates a broken and an intact actuator rod, both inserted into a brass plug. An actuator rod received in a bent condition is shown on Photo 6. The threaded section of a non-broken actuator rod was measured as 1.9 inch and its shank as 2.3 inches. The diameter was measured as 0.21 inch.

2.4 The 64 valves were received in three different conditions:

a) with a brass plug with or without actuator rod remains;
b) with rubber plugs;
c) without plugs.

Eighteen valves were received with a brass plug, of which 14 had actuator rods inserted into the brass plug. All of these 14 actuator rods were fractured. Four non-broken actuator rods were also received; hence, the total number of brass rods received matched the number of brass plugs. The individual valve conditions are as listed in Table 2 with Photo 4 showing the three types. The rubber plugs found on 22 valves had a molded, crosswise slit in them to prevent any pressure differential buildup behind the plug. In service operation, the micro command switch on the mimic ballast control panel energizes a relay, which in turn allows electrical current to operate the associated solenoid control valve using 115 volts AC. In an emergency, the solenoid valves can be activated manually, through the use of actuating rods inserted into a brass plug.

2.5 Photos 7 and 8 show the various valve components. Photo 8 is a cross section of the internal valve mechanism. The components, numerically identified on Photos 7 and 8, are listed below:

1. solenoid housing and gasket;
2. solenoid core;
3. solenoid;
4. plastic keeper;

Solenoid Valves	Butterfly Valves
1, 2, 3, 4	Ballast water tanks
5, 6	Drill water tanks
7, 8, 9, 10, 11	Ballast water tanks
12, 13	Drill water tanks
14, 15, 16	Ballast water tanks
17, 18, 19	Drill water pump to tanks
20	Ballast water manifold
21, 22, 23	Emergency bilge suction
24, 25, 26	Ballast water pumps to manifold
27	Ballast water manifold
28, 29	Drill water service
30	Overboard
31	Sea water tank
32	Sea chest

TABLE 1

SOLENOID CONTROL VALVES AND CORRESPONDING BUTTERFLY VALVES PORT AND STARBOARD

5. spool fitting inside the sleeve;
6. sleeve with its six "O" rings;
7. spool return spring;
8. main valve body with its five chambers for the air flow;
9. back plate and gasket.

The solenoid core is normally pulled electrically to actuate the valve. In an emergency, it can be pushed manually by insertion of the brass actuator rod against the spool, which then moves within the sleeve, allowing the air flow to travel within the valve chambers.

2.6 A copy of drawing NMA 298-2, shown as Figure 2, illustrates the air system. The typical assembly of a solenoid bank is comprised of an intake and exhaust manifold, a sub-plate for each valve and the 10 or 11 valves as shown on Photo 9. Each manifold has three isolated air ducts in which the air flows through the individual valves. The air ducts constitute the air supply in the middle, and two exhausts, one on each side. The 90 psi air travels through the manifold ducts, sub-plate ports and valve chambers. The ports and chambers are identified on Photo 10 as E1 and E2, S, and C1 and C2; for exhausts 1 and 2, supply and cylinders 1 and 2 respectively. When in a non-activated position, this air escapes through the exhaust; and when in an activated position, the air is directed to the butterfly valves' piston.

2.7 The activated and non-activated sleeve-spool positions are shown on Photos 11 and 12 to illustrate the air flow direction. In the non-activated position, the air flows from "S" to "C1". Since the two cylinder 1 exhausts are normally sealed on both sides as shown on Photo 13, the air is trapped inside the valve. When the spool is pushed during activation, the air travels from "S" to "C2" and then to the opened cylinder 2 control line leading to the tank butterfly valve. The air previously trapped inside the valve in the non-activated position is bled to the manifold exhaust line through "E1", as "C1" and "E1" now interconnect. When the spool returns to the non-activated position, "C2" and "E2" interconnect and the air bleeds to the manifold exhaust line through "E2", and the butterfly valve returns to its closed position.

2.8 To verify the state of the solenoid valves, micrometer measurements of the positions of the solenoid cores were taken on all valves. These measurements are listed in Table 3 for the valves with brass plugs, and in Table 4 for the valves without brass plugs. (The measurements are identified numerically from 1 to 4, as shown on Photos 14 and 15). It can be observed that only measurement #3 can be made when no actuator rod is present, but all four measurements can be made with the actuator rod present. Measurement #3 gives the solenoid core depth with reference to the exterior surface of the valve solenoid housing. The average value measured was 0.72 inch for the valves with brass plugs, and 0.52 inch for the valves without. One valve (P-13) which was received with a brass plug had a 0.65 reading for measurement #3, more than halfway between those with and without brass plugs.

with brass plugs				with rubber plugs		without plugs	
with actuator rod		without actuator rod					
Starboard	Port	Starboard	Port	Starboard	Port	Starboard	Port
S1	P2	S2	P13	S4	P3	S5	P1
S3	P11		P14	S18	P8	S11	P4
S6	P12		P15	S19	P9	S12	P5
S7	P16			S20	P10	S13	P6
S8				S23	P17	S17	P7
S9				S25	P18	S21	P19
S10				S27	P22	S22	P20
S14				S28	P23	S24	P21
S15					P24	S26	P28
S16					P25	S29	P30
					P26	S30	P31
					P27	S31	
					P29	S32	
					P32		

TABLE 2

THE THREE GROUPS OF SOLENOID CONTROL VALVES AS RECEIVED

2.9 The fourteen actuator rods found in the valves had been fractured. The fracture surface of these broken rods was analysed using scanning electron microscopy. All fourteen fracture surfaces were consistent with ductile bending overload failures characterized by a rough, irregular surface, as shown on Photo 16. In each case, the fracture originated in a thread root, Photo 17 and was accompanied by one-way bending deformation adjacent to the fracture.

2.10 Each one of the sixty-four solenoid core faces was examined for actuator rod imprints. All of the faces from the valves where brass plugs were found had a visible and distinctive circular mark. A typical mark, as observed, is shown in Photo 18, which is a scanning electron micrograph using backscattered electron imaging to differentiate the different elements. The circular brass marking diameter was about 0.16 inch. No deformation of the core surface was observed. Four valves (P10, S11, S12 and S13), received without brass plugs, exhibited a deep circular imprint on their solenoid core faces. When individually examined with the scanning electron microscope using backscattered electron imaging, these imprints did not show the typical brass marking observed for the valves found with brass plugs in place, and the imprint diameter was on average 0.11 inch. Some deformation of the core surface was also observed. A typical imprint is shown on Photo 19.

2.11 In their as received condition, none of the 64 solenoid valves could be operated manually because the mechanism was sticking, probably as a result of the lubricant emulsification. Debris was also found in various areas of the valve interior. Once cleaned, the average force required to manually activate the valve by pushing directly on the solenoid core was found to be three pounds for the thirteen valves tested, a force easily overcome by inserting the brass actuator rods. The maximum displacement of the solenoid core and valve spool was measured as 0.20 inch. In the cleaned condition, the solenoid core returned to its non-activated position when the acutator rod was unscrewed.

2.12 Debris was found inside most of the valves. Representative samples were selected and forwarded to the Division of Chemistry at the National Research Council of Canada. The results of the analysis showed that there was no evidence that the fibrous material and the metallic particles found were present inside the valves prior to the valve immersion in sea water. The fibrous material was consistent with fibres originating from marine sponge. The metallic particles found were rust (Fe_2O_3) and alumina (Al_2O_3) which typically result from salt-water corrosion of the iron and aluminum valve components.

2.13 Sixty-three of the sixty-four valves were electrically tested and found to function properly. (The sixty-fourth valve was made available to the Royal Commission for their testing in St. John's, Nfld.). The minimum voltage required to electrically activate the valve was measured as 76 volts on average. The solenoid core was pulled into the activated position immediately upon application of the proper voltage, and similarly released when the voltage was removed.

2.14 A solenoid control valve was tested for leakage under the operational air pressure of 90 psi. The air supply was first admitted through the manifold air supply duct, with the sub-plate cylinder 2 exhaust for all the valve sub-plates blocked off. The air supply was then admitted through the sub-plate cylinder 2 exhaust of the valve. In both cases, a minimal amount of leakage was observed at any of the manifold exhausts, and no significant drop in pressure was noted. The valve was then tested for activation, with a 115 volts AC voltage supply and an internal pressure of 74 psi. The pressure drop was about 2 psi as measured at the sub-plate cylinder 2 exhaust.

Valve	Displacement (inches)			
	#1	#2	#3*	#4
S1	0.665	0.555	0.715	1.190
S2	Rod missing	0.580	0.725	N.A.
S3	0.640	0.510	0.720	1.160
S6	0.650	0.510	0.730	1.135
S7	0.710	0.590	0.730	1.230
S8	0.655	0.560	0.722	1.195
S9	0.730	0.535	0.720	1.185
S10	0.690	0.595	0.715	1.240
S14	0.760	0.620	0.725	1.275
S15	0.645	0.480	0.725	1.115
S16	0.700	0.545	0.725	1.185
P2	0.670	0.550	0.725	1.205
P11	0.690	0.555	0.725	1.205
P12	0.635	0.560	0.730	1.205
P13	Rod missing	0.600	0.655	N.A.
P14	Rod missing	0.550	0.715	N.A.
P15	Rod missing	0.580	0.720	N.A.
P16	0.650	0.630	0.720	1.270

TABLE 3

MICROMETER MEASUREMENTS FOR VALVES WITH BRASS PLUGS

(Refer to Photos 14 and 15 for location of measurements 1 through 4)

*NOTE: Measurement #3 average 0.723 inch. Valve P13 was not included in this average calculation, since its measurement #3 was not in line with the others.

DISCUSSION

3.1 The 64 solenoid control valves were received in either an activated or non-activated position. The state of activation or non-activation was determined from micrometer depth measurements of the solenoid core position. All 18 valves which were received with a brass plug were found to be in the activated position. (This includes valve P13 for which measurement #3 was more than halfway between those valves with brass plugs and those without. It is considered that enough air pressure would have been available to the associated control butterfly valve to open it.) The remaining valves with rubber plugs or no plugs were in a non-activated position. It was established that the rubber plugs found on 22 of the valves played no role in the valve activation. The long period of immersion under sea water resulted in the emulsification of the valves lubricant, thereby causing sticking of the mechanism which could consequently be later determined as activated or non-activated.

3.2 From both optical and scanning electron microscopy analysis, it was determined that all 14 broken actuator rods failed from bending overload. No evidence of torsional overload was found.

3.3 Direct evidence of material transfer from the brass actuator rods onto the solenoid core surface was found for all 18 valves received with brass plugs. No such material transfer evidence was found on any other solenoid core. The deep circular imprints observed on four solenoid cores from valves other than those received with brass plugs was made with a device of a harder material than the iron solenoid core, thereby causing some deformation of the core surface. These deep circular imprints were found to be of a smaller diameter than those made by the brass actuator rods. The force required to activate a valve manually was very small, and only a few seconds (5 to 10) would be required to fully activate the valve manually, once the actuating rod was in place.

3.4 Analysis of the debris materials found inside the valves revealed that they were a direct result of the valves having been submerged at the bottom of the sea for a long period of time, and were not present prior to the accident.

3.5 Testing of the valves demonstrated that they were all serviceable prior to the accident.

3.6 Pressure testing of the valves showed that minimum leakage was present under applied operational pressure.

Valves Port	Measurement #3 (inches)	Valves Starboard	Measurement #3 (inches)
P1	0.522		
P3	0.527		
P4	0.524		
P5	0.525		
P6	0.516	S4	0.522
P7	0.525	S5	0.599
P8	0.523	S11	0.531
P9	0.525	S12	0.526
P10	0.529	S13	0.526
P17	0.524	S17	0.536
P18	0.528	S18	0.519
P19	0.536	S19	0.531
P20	0.529	S20	0.540
P21	0.524	S21	0.519
P22	–	S22	0.525
P23	0.533	S23	0.522
P24	0.527	S24	0.520
P25	0.525	S25	0.527
P26	0.515	S26	0.519
P27	0.522	S27	0.525
P28	0.514	S28	0.528
P29	0.529	S29	0.528
P30	0.522	S30	0.521
P31	0.498	S31	0.525
P32	0.533	S32	0.526
Average	0.524 inch	Average	0.529 inch

TABLE 4

MICROMETER MEASUREMENTS FOR VALVES WITHOUT BRASS PLUGS

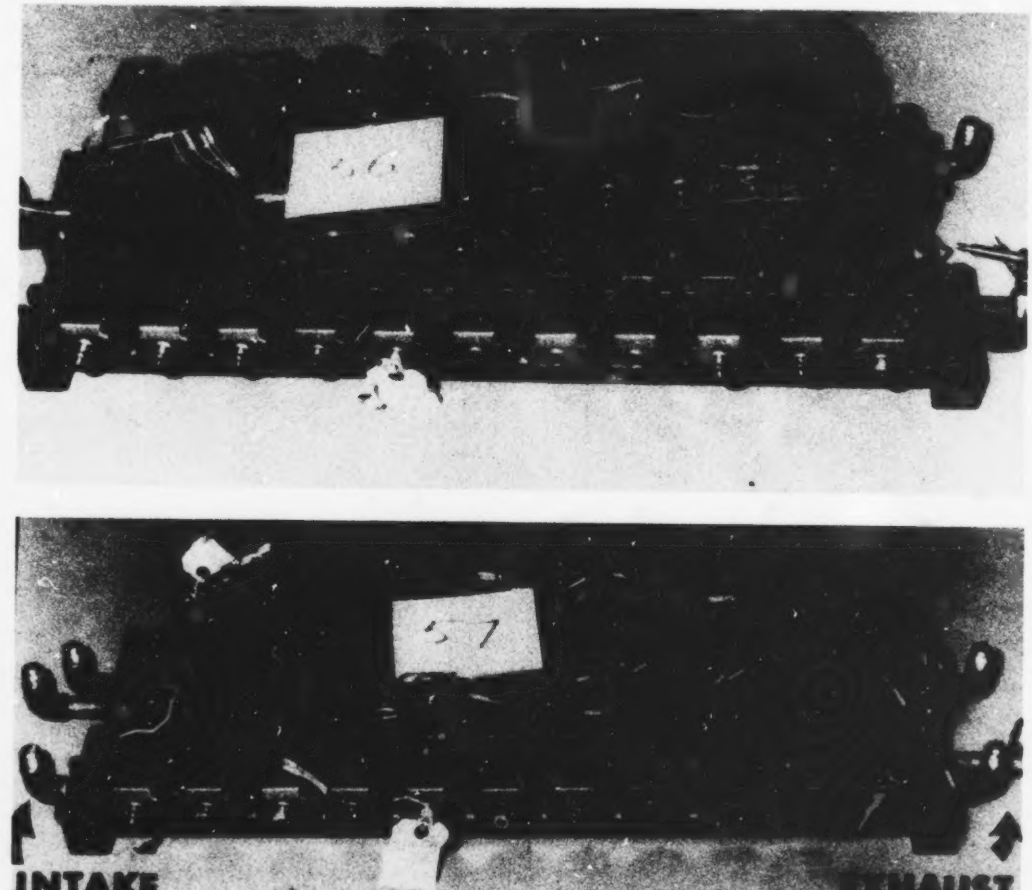
(Refer to Photo 14 for location of measurement #3).

Average value of all measurements: 0.526 inch

CONCLUSIONS

4.1 In response to the Royal Commission's specific questions (refer to Paragraph 1.2, questions (a) through (i) respectively):

a) there was positive evidence that all those valves found with brass plugs inserted had been manually operated;
b) the rubber plugs found on 22 of the valves were slit crosswise to prevent pressure differential buildup and could not have been pushed inside the valve solenoid housing, nor were any so found;
c) only those solenoid control valves received with brass plugs were found in the activated position. They were concluded to be the only valves manually activated at the time of the accident;
d) all of the valves received with brass plugs exhibited some material transfer from the rods onto the solenoid core faces. None of the valves received without brass plugs exhibited such material deposits. Manipulation of the brass plugs and actuator rods from one valve to the other would have resulted in some of the valves received without brass plugs exhibiting some similar brass markings, since these would not wash away from the solenoid core surface during immersion on the sea floor. Hence, it may be concluded that none of the valves received without brass plugs had been manually operated during the accident sequence. The imprints found on P10, S11, S12 and S13 solenoid core faces were most likely the result of testing prior to the accident with a non-brass rod, and therefore are not considered to be related to the accident;
e) the debris materials found inside the valves were a direct result of the valves submersion in sea water for a long period of time. No evidence was found that any of this debris was present prior to the accident and caused a valve malfunction;
f) the inserted actuator rods held each valve mechanism into an activated position during the accident. Once submerged, the salt-water emulsified the valves' lubricant, causing the valve mechanism to stick. This prevented the manually activated valves from returning to a non-activated position once their brass actuator rod was removed. Since none of the valves received without brass plugs were found in an activated position, it can be concluded that they were either not activated at the time of the accident, or that their mechanism returned to a non-activated position as soon as their electrical power supply was removed;
g) no leakage of any significance was found during testing of the valves using the normal operating air pressure;
h) testing of the valves indicated that they were serviceable prior to the accident;
i) the broken actuator rods all failed through bending overload, and were considered most likely to have all been broken when the solenoid valve banks were being retrieved from the wreckage, and not prior to or during the accident.


56
57
INTAKE
EXHAUST
#59

PHOTOS 1-3 The six solenoid valve banks as received. The manifold intake and exhaust ends are indicated in the centre photograph.

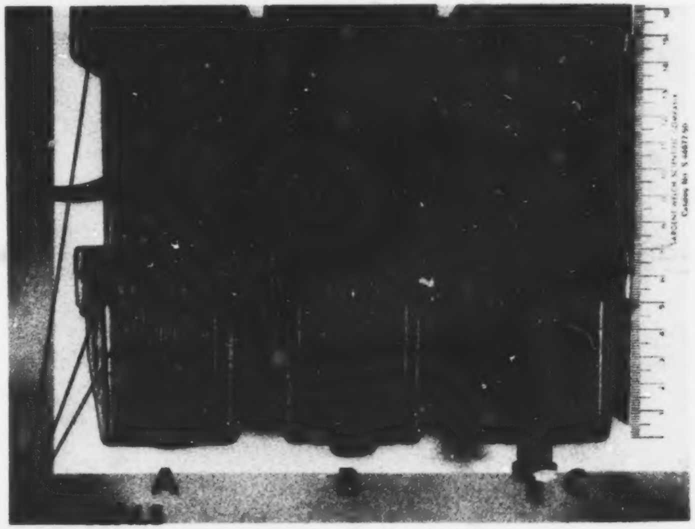

A
B
C
SARGENT-WELCH SCIENTIFIC
Catalog No. S-44677-50

PHOTO 4 Samples of solenoid valves: without rubber plug or brass plug, *A*, with a rubber plug, *B*, with a brass plug and actuator rod remnant, *C*. Note brass plate lettering and plastic label tapes.

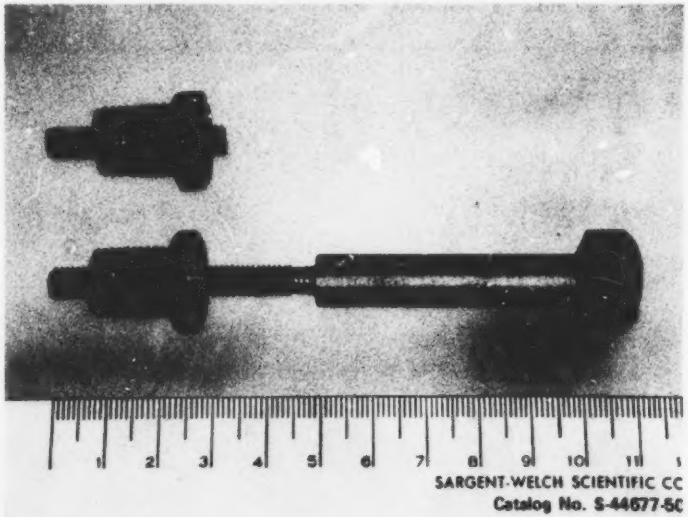

1
2
3
4
5
6
7
8
9
10
11
SARGENT-WELCH SCIENTIFIC CC
Catalog No. S-44677-50

PHOTO 5 A broken and intact actuator rod, inserted into a brass plug.

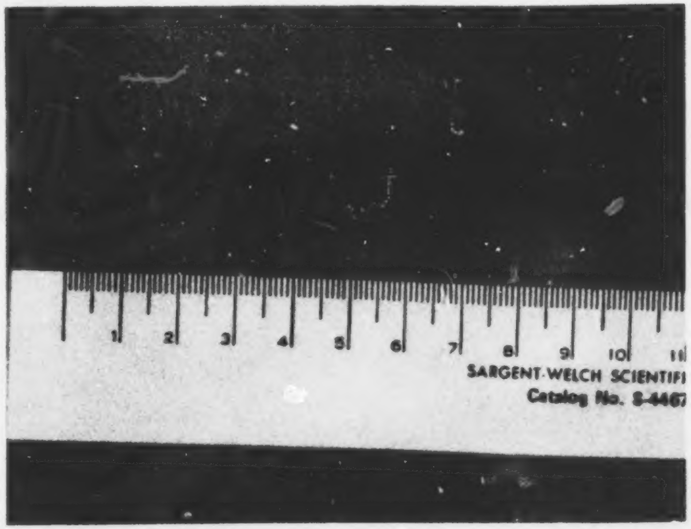

1
2
3
4
5
6
7
8
9
10
11
SARGENT-WELCH SCIENTIFI
Catalog No. S-4467

PHOTO 6 A bent actuator rod, as received.

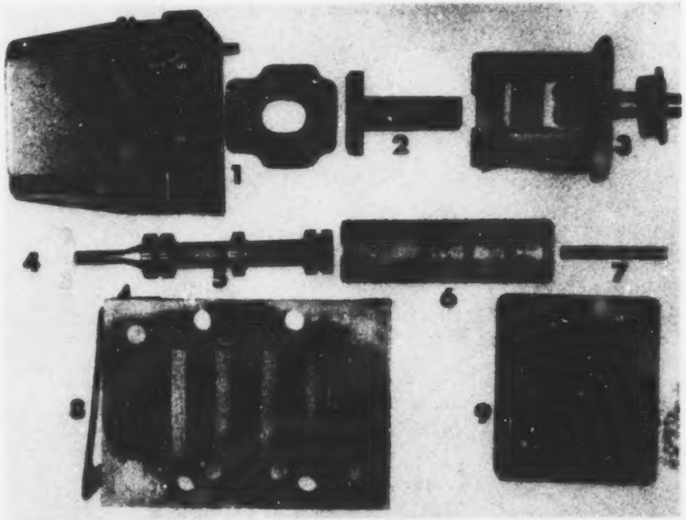


PHOTO 7 The various solenoid valve components: 1) front cover and gasket 2) solenoid core 3) solenoid 4) plastic keeper 5) spool 6) sleeve 7) spring 8) main valve body 9) back plate and gasket.

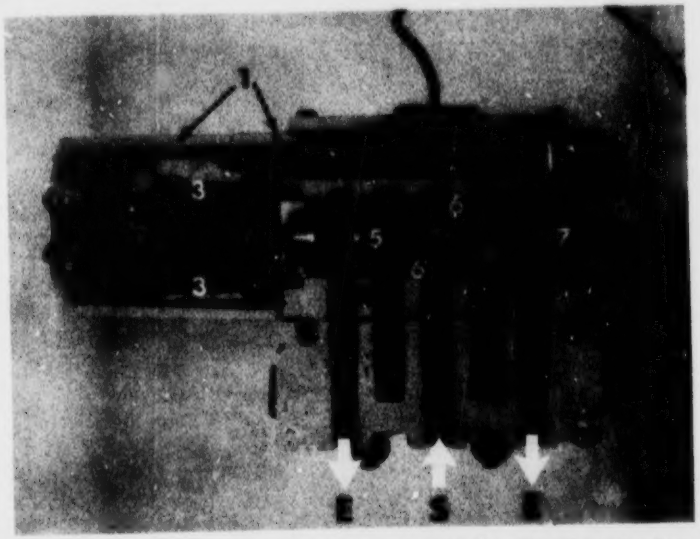


PHOTO 8 Cross-section of a valve, illustrating the internal mechanism. The same numerical identification as in photo 7 is used. The air supply and two exhausts are respectively arrowed as *S* and *E*.

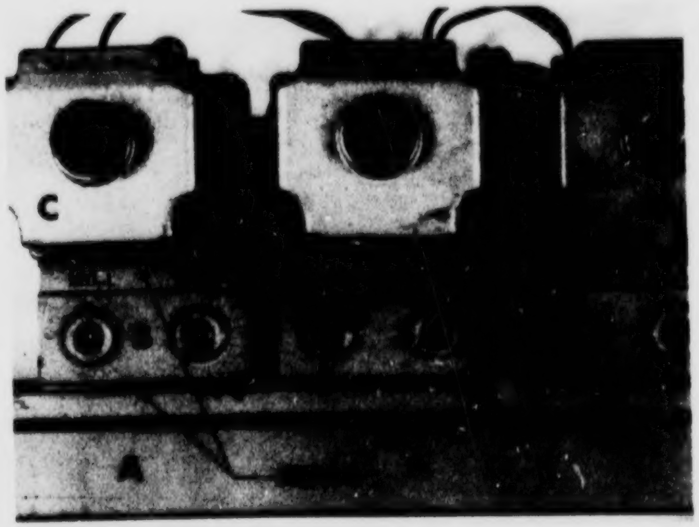


PHOTO 9 Typical assembly of a solenoid valve bank: manifold *A*, sub-plate *B* and valve *C*. Note the rubber plugs on two of the valves.

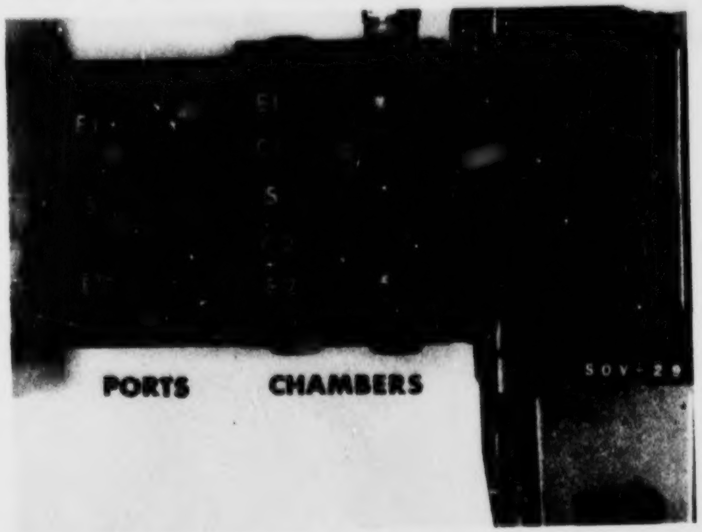

E1
S
PORTS
CHAMBERS
SOV-29

PHOTO 10 The manifold ports and the valve and sub-plate chambers are identified on this photograph.

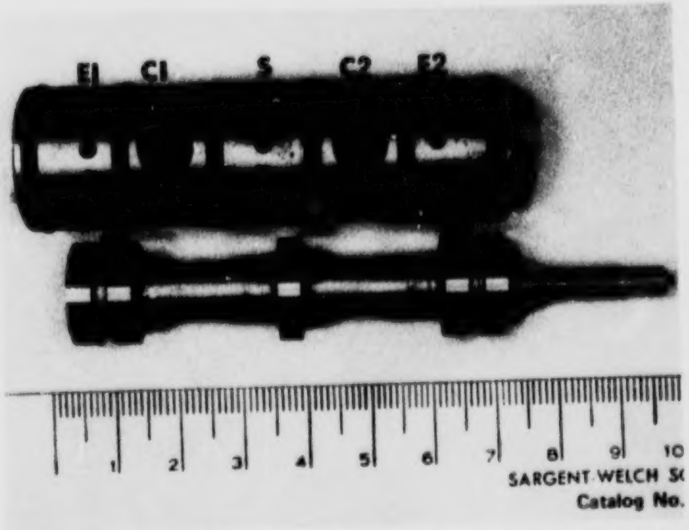

E1
C1
S
C2
E2
1
2
3
4
5
6
7
8
9
10
SARGENT WELCH S
Catalog No.

PHOTO 11 The sleeve and spool are shown separated but aligned, in the non-activated valve position. The relationship between the sleeve and the valve chambers is indicated by E1, C1, S, C2, and E2.

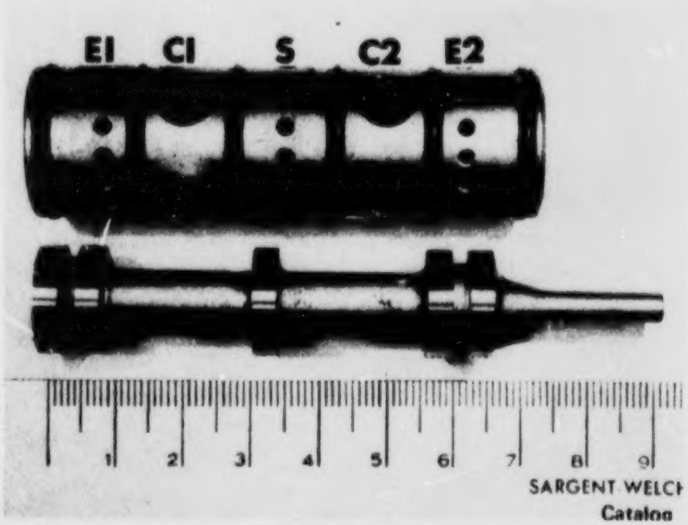

EI
CI
S
C2
E2
1
2
3
4
5
6
7
8
9
SARGENT WELCH
Catalog

PHOTO 12 The sleeve and spool are shown separated but aligned, in the activated valve position. The relationship between the sleeve and the valve chambers is indicated by E1, C1, S, C2 and E2.

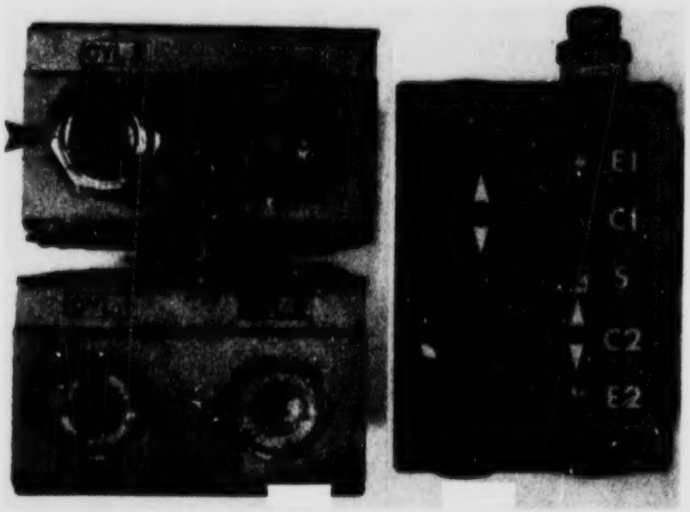
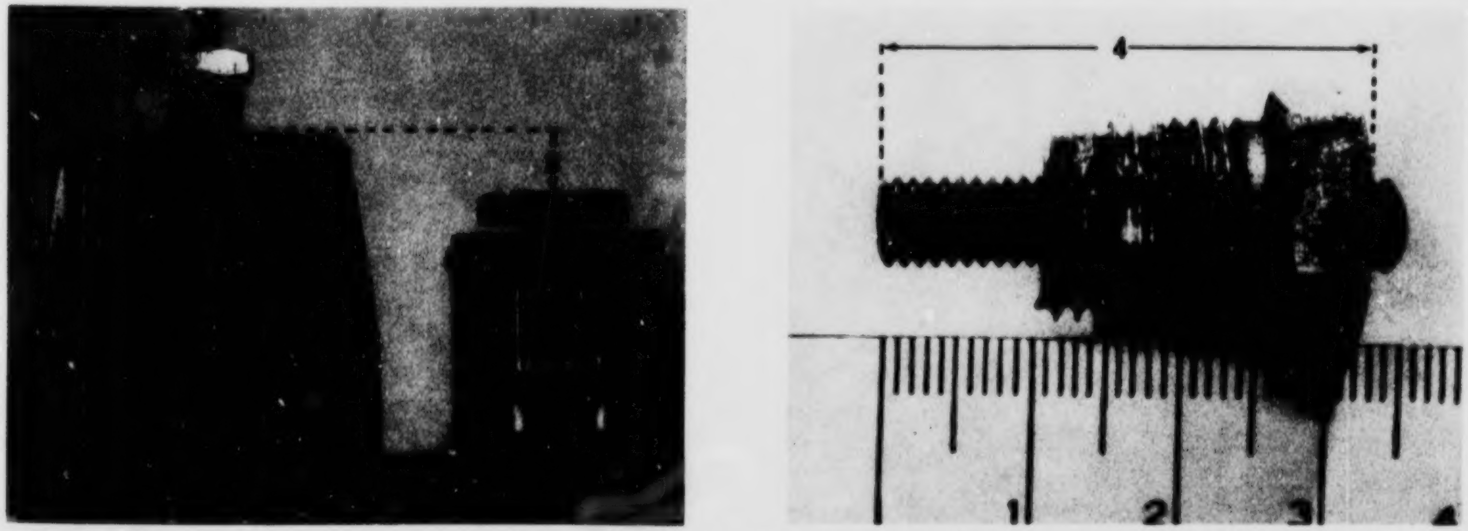


PHOTO 13 The sub-plate front and rear view are shown on the left. The arrow points to the only opened exhausts. The sub-plate top view with the air flow direction from *C1* and *C2* is shown on the right.



PHOTOS 14-15 The four micrometer measurements compiled in tables 3 and 4 are shown here with the reference numbers used in those tables.

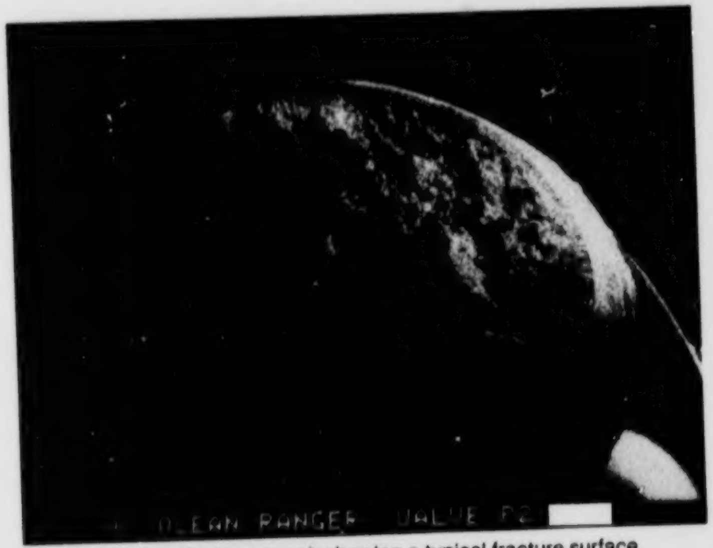


PHOTO 16 SEM photograph showing a typical fracture surface observed in all of the 14 broken actuator rods.

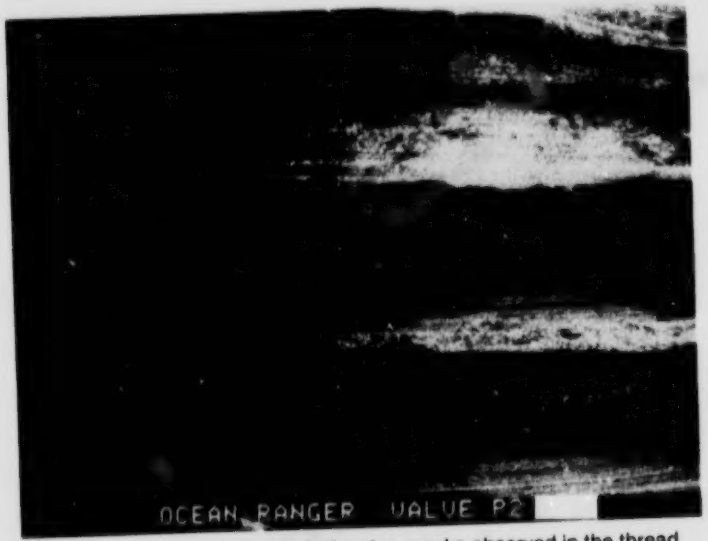


PHOTO 17 SEM photograph showing cracks observed in the thread roots of a failed actuator rod. This was typical for all 14 broken actuator rods examined.

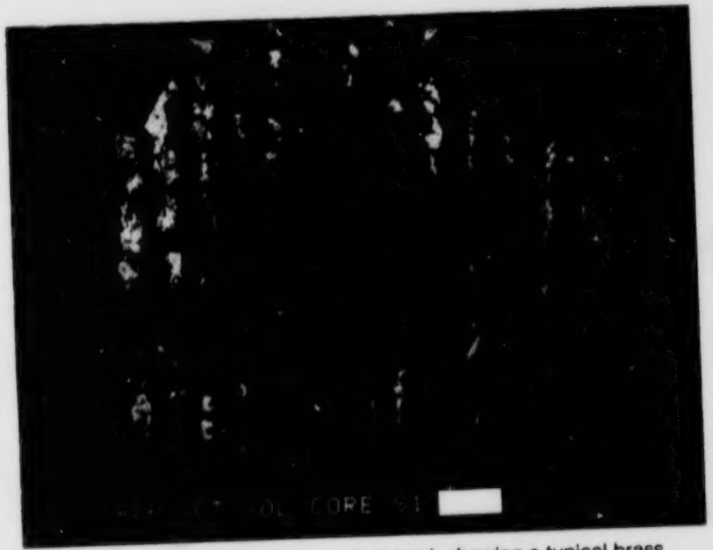


PHOTO 18 Scanning electron micrograph showing a typical brass marking observed on the solenoid core face of valve S1.

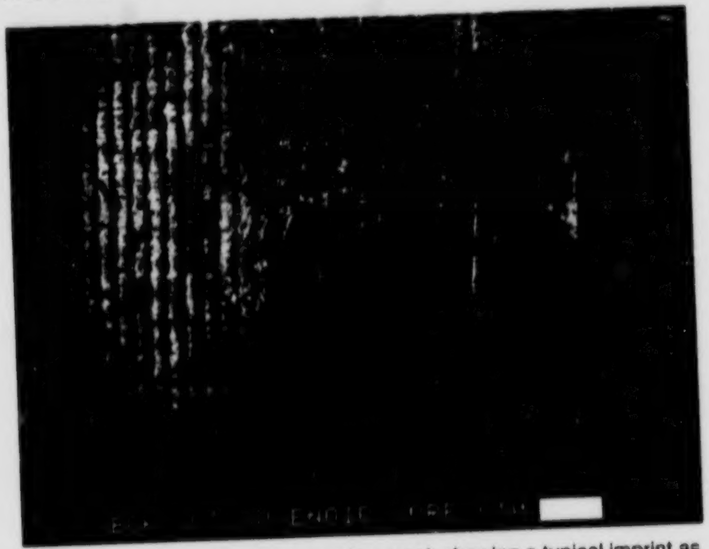


PHOTO 19 Scanning electron micrograph showing a typical imprint as observed on the solenoid core faces of valve P10, S11, S12 and S13.

ARRANGEMENT OF THE 64 SOLENOID VALVES UNDER THE BALLAST CONTROL CONSOLE INDICATING THE CONDITION AS FOUND

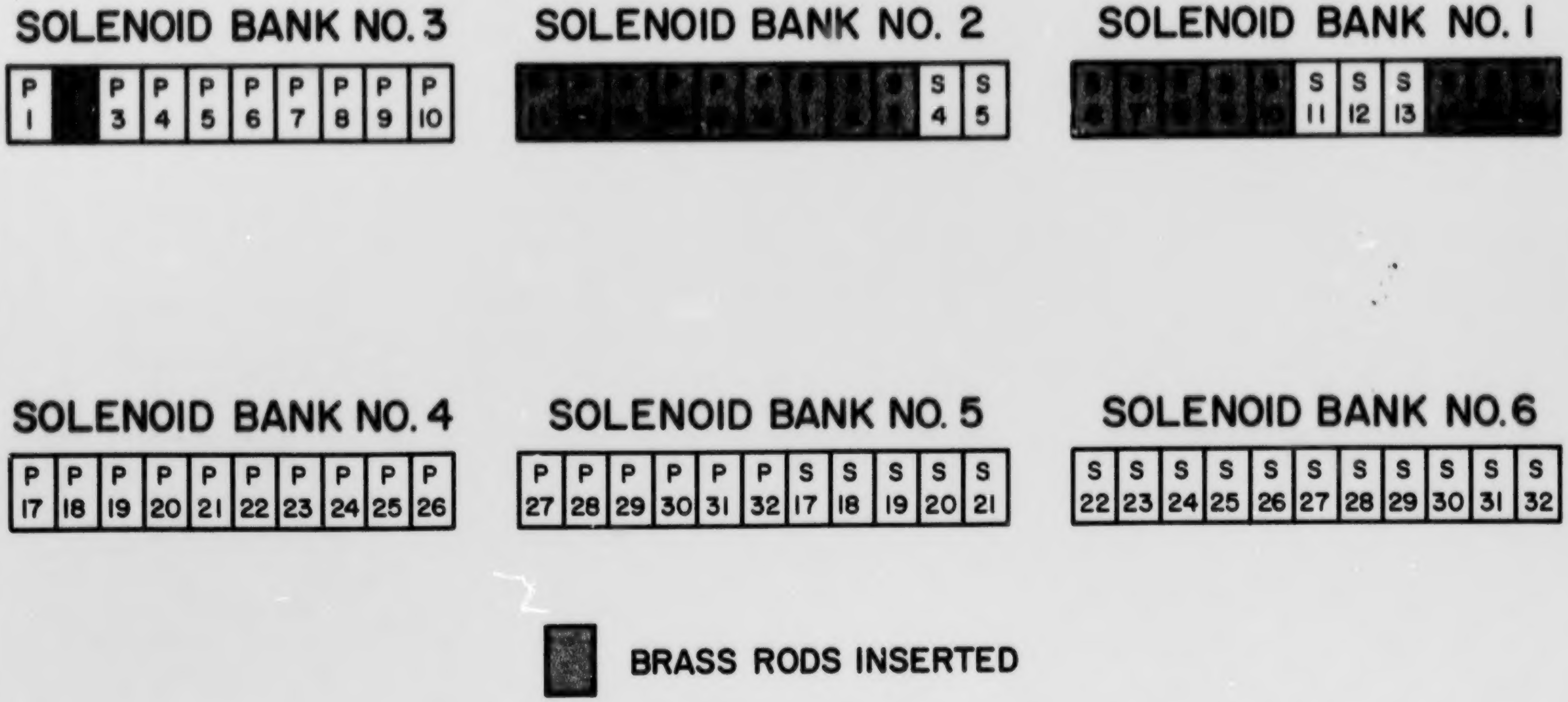

SOLENOID BANK NO. 3
P 1
P 3
P 4
P 5
P 6
P 7
P 8
P 9
P 10
SOLENOID BANK NO. 2
S 4
S 5
SOLENOID BANK NO. 1
S 11
S 12
S 13
SOLENOID BANK NO. 4
P 17
P 18
P 19
P 20
P 21
P 22
P 23
P 24
P 25
P 26
SOLENOID BANK NO. 5
P 27
P 28
P 29
P 30
P 31
P 32
S 17
S 18
S 19
S 20
S 21
SOLENOID BANK NO. 6
S 22
S 23
S 24
S 25
S 26
S 27
S 28
S 29
S 30
S 31
S 32
BRASS RODS INSERTED

FIGURE 1

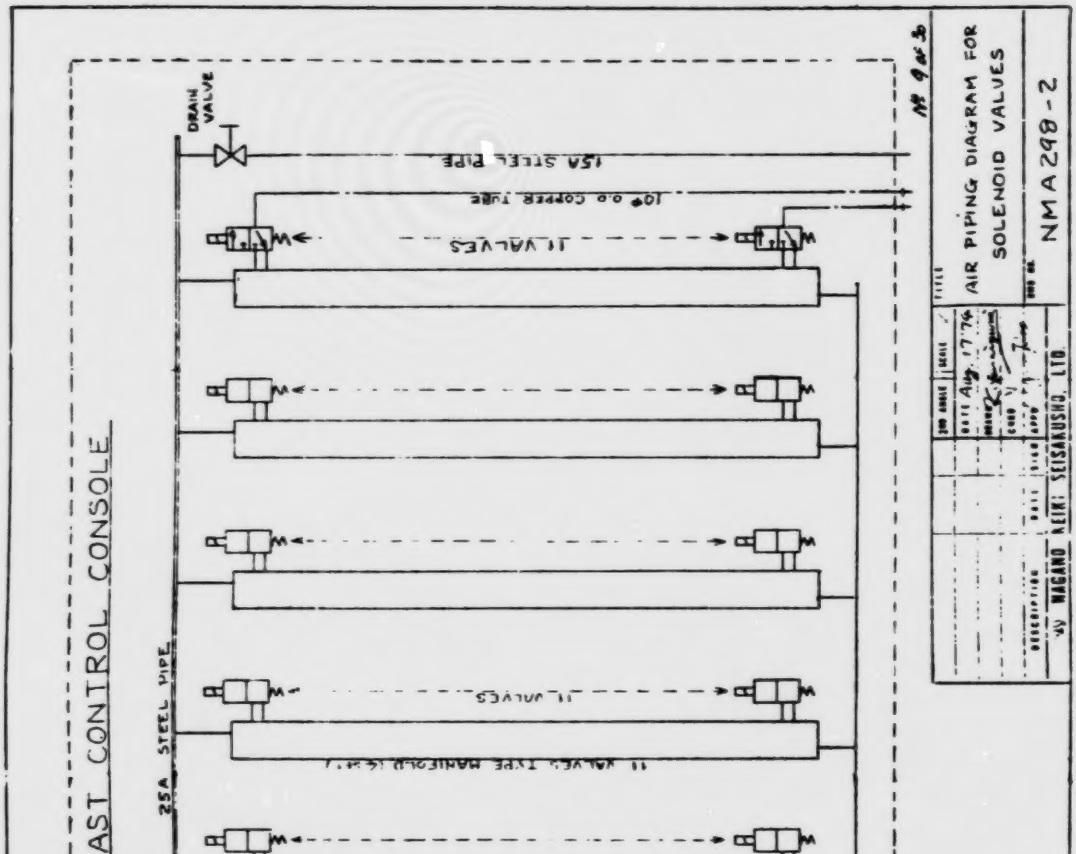

BALLAST CONTROL CONSOLE
COMPRESSED AIR (4 kg/cm²) (25A STEEL PIPE)
AIR FILTER
AIR REGULATOR
LUBRICATOR
RELIEF VALVE
PRESS. GAUGE
SOLENOID VALVE (60 SET)
25A STEEL PIPE
15A STEEL PIPE
15A STEEL PIPE
15A STEEL PIPE
DRAIN VALVE
10 VALVES
11 VALVES
11 VALVES
10 VALVES TYPE MANIFOLD (2 SET)
11 VALVES TYPE MANIFOLD (4 SET)
10φ o.o COPPER TUBE
10φ o.o COPPER TUBE
TO BUTTERFLY VALVE 10φ o.o COPPER TUBE
EXH. PIPE
ATM.
No 9 of 3
AIR PIPING DIAGRAM FOR SOLENOID VALUES
NMA298-2
DATE Aug. 17 '76
NAGANO KEIKI SEISAKUSHO, LTD.

FIGURE 2

REPORT "D"

ENGINEERING REPORT EP 331/83

BALLAST CONTROL MIMIC PANEL ANALYSIS

8 September 1983

INTRODUCTION

1.1 The Royal Commission investigating the *Ocean Ranger* Marine Disaster requested the Aviation Safety Engineering (ASE) Facility, of the Aviation Safety Bureau, Transport Canada to assist in the investigation by conducting certain tests and analyses on the ballast control mimic panels recovered from the sunken rig.

1.2 The four panels received are shown in Photos 1 to 4. These photos were taken on the diving vessel shortly after being retrieved from the *Ocean Ranger* ballast control room in July 1982. At that time the panels were hosed down with fresh water and then sprayed with WD-40 to remove as much water as possible in order to try and prevent further corrosion of the switches. On receipt of the four panels by ASE, from the Royal Commission, the following was specifically requested:

1) photograph and identify all control and pump switches and manual valve indicators prior to any testing;
2) examine all switches and indicators for any evidence of burning or charring;
3) examine all switches and indicators for any evidence of arcing across light bulb contacts;
4) record the number of light bulbs in each switch and indicator and determine whether they are operative or not;
5) examine in detail for any evidence of arcing on the contacts of the microswitches contained in the following switch assemblies: port/starboard switches 1 to 16 inclusive, 20, 27, 30 and 32.

EXAMINATION

2.1 The four panels recovered and forwarded to the ASE facility were the port and starboard tank valve mimic panels and the port and starboard pump room mimic panels as shown in Photos 1 to 4 and described in drawings NMA298-1-1 and 2 attached as Figures 3 and 4.

2.2 The tank mimic panels contained normally 16 pairs of micro command switches numbered 1 to 16 each. It was noted that switches P-2 and P-8 were missing. The pump room panels contained 16 pairs of micro command switches, 10 pairs of indicators and 6 pairs of pump switches which were identified by pump function. Indicator S-35 and the lampholder of switch P-17 were found missing. Also 10 of the 12 red pump stop buttons and 4 of the 12 green pump run buttons were missing, however their light bulbs were still in situ. This is all evidenced in Photos 1 to 4.

2.3 The panels had routing diagrams engraved on them relating each switch and indicator function to the ballast control system in a schematic way, see drawings NMA298-1-1 and 2, Figures 3 and 4.

2.4 The panels appeared to be relatively clean and undamaged. Little or no corrosion was found on the exterior of the switches, its terminals and wiring. The panels themselves were made of stainless steel and were not affected by corrosion. However, the paint which highlighted the engraved lines of the mimic piping diagram was peeled loose in several places as is evident in Photos 2 and 4. Only one switch (P-19) was found to be damaged by sparking and burning around its terminals. This switch is shown in Photo 5. No evidence of soot or blackening (typically the result of burning or sparking) could be found anywhere on the panels except that found on switch pair P-19.

2.5 The wiring for all switches and indicators on the panels was of the same type. It appeared to be 18 gauge with PVC insulation. The insulation was grey in color and much heavier and stiffer than is considered normal for this type of application.

2.6 Each switch pair had 10 soldered connections on 8 terminals and the indicators 5 connections on 4 terminals. The pump switch pair had screwed on lug terminals counting 12 connections on 8 terminals. This gives a total 740 soldered connections on 96 terminals. All terminal connections were exposed as is evident from Photos 5 to 9 which show the back (or underside) of the panels.

2.7 The switches removed from the panels were identified as follows: 62 pairs of micro command switches part number MCN-22-M10, 19 pairs of indicator lights part number MCN-23 both manufactured by IZUMI Denki of Japan; 12 pump switches "red" part number LS-4031E-11R, and 12 pump switches "green" part number LS-1031E-11G both manufactured by Tokyo Denki of Japan. The micro command switches and indicators were designed to accommodate two light bulbs each. However, they were all wired for only one light bulb each. After removal from the panel all switches were photographed in profile on 35 millimeter slides. These slides will be submitted to the Commission with this report.

2.8 The micro command switch construction is depicted in Figure 1. The switch pair as part of the butterfly valve control system is shown in Figure 2 in schematic form. It is indicated by the two areas enclosed by dash lines. From this schematic it is evident that the light bulbs and microswitches of the switch pair are in separate circuits and only relate to each other through the butterfly valve limit switches and the relay contacts.

2.9 Microscopic examination of all light bulb contacts did not reveal any evidence of arcing or burning. Some minor corrosion was found on most contacts; however, this could be attributed to the panels' six month submersion in salt-water. Except for switch pair P-19 none of the valve switches showed any evidence of damage.

2.10 Detailed microscopic examination of the 76 Burgess V4T6 microswitches removed from the micro command switch pairs P1 to 16, 20, 27, 30 and 32 (switches P-2 and P-8 were missing) and S1 to 16, 20, 27, 30 and 32 did not reveal any evidence of arcing on their contacts. Photo 10 shows one of these microswitches with part of its casing removed to reveal its mechanism. All these microswitches were photographed, revealing their mechanism, on 35 mm slides. These slides will be submitted to the Commission with this report.

2.11 The Manual Valve Indicators port/starboard 33 to 41 (S-35 was found missing) were examined for any evidence of damage, such as charring, burning or arcing. No such damage was found on any of the 19 Indicators examined. The light bulb contacts revealed slight corrosion similar to the corrosion found on the switches.

2.12 The pump switches were of a much different design than the micro command switches, as is evident from Photos 11 and 12. A pump switch pair consisted of a momentary push button "run" switch, with a green indicator light which when depressed engaged a self-holding relay which switched "ON" the pump, a self-latching push button "stop" switch, with a red indicator light which when depressed released the relay and stopped the pump. The "stop" button had to be pressed again for the red light to go off and to allow the green run button to be effective. The 18 volt light bulb in the push button of these switches was powered directly from the 115 volt control circuit through a small transformer built into the switch just below the push button, as is evident in Photo 13. The actual switch mechanism was located at the bottom of the switch body, see Photo 13. No arcing or burning damage was found in any of the 24 pump switches in the panels.

2.13 The four panels normally contain one light bulb in each of the 152 switches and 40 indicators. Two switches and one indicator pair plus two light holders were found missing, making the total number of light bulbs examined 184. Of these 184 bulbs 80 were found to have fractured filaments. The analysis of these light bulbs is covered in ASE Report "E", (EP 332/83). All 80 blown light bulbs have been photographed on 35 mm slides and will be submitted to the Commission with this report.

2.14 Switch pair P-19 was the only component found damaged on the panels (except for the light bulbs). Only the "green" switch was damaged, as is evident in Photos 5 and 14. The "red" switch did not show any damage at all. The microswitch housing showed heat damage near the common terminal of the microswitch and a light bulb terminal which was burned off.

DISCUSSION

3.1 The burning of the "green" switch P-19 most likely occurred as a result of sea water ingestion causing a conductive pass between ground and the 115 volt circuit via the metal structural parts of the micro command switch, the metal panel and the 115 volt terminal. It is considered very likely that this switch is the very site where the 115 volts AC "leaked" into the 24 volt AC lamp circuit, causing 68 lights to burnout.

3.2 As is evident from Photo 13 the 18 volt secondary terminals and 115 volt primary terminals in the pump switches are very close together. When the panels were flooded, sea water most likely entered the pump switches at the transformer terminals and shorted the primary to the secondary contacts, leaking the 115 volts into the 18 volt light bulb and blowing the filament with an over-voltage. This occurred only at those pump lights which were lit.

CONCLUSIONS

4.1 All required photographs were made and will be submitted to the Commission with this report.

4.2 No evidence of burning, charring or arcing was found on any of the panels' components, except for the P-19 "green" switch.

4.3 All switches and indicators were wired for only one light bulb. None of them were found with light bulbs missing, except P-17. However, the lamp housings were also missing in this switch pair.

4.4 Eighty of the 184 light bulbs examined had blown filaments.

4.5 A detailed analysis of the light bulb failures is covered in ASE Report "E", (EP 332/83).

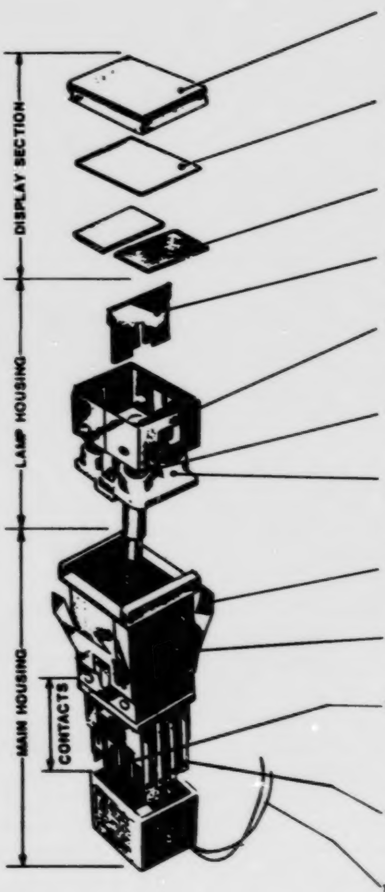
4.6 The lower part of the microswitch housing on switch "green" P-19 showed evidence of arcing damage and burning; probably as the result of sea water-assisted shorting between the 115 volt terminals and ground via metal structure in the switch body.

4.7 The shorting of switch "green" P-19 was most likely the site of leakage of the 115 volts into the 24 volt lamp circuit, causing the 68 light bulbs to blow.

4.8 No evidence of any arcing in any of the microswitches examined could be found.

CONSTRUCTION IZUMI

MICRO COMMAND CONTROL LIGHT
TYPE MCM23-22-280-13-15-27



1) Front lens
Face plate used as pushbutton to operate switches. Made of transparent acrylic resin, slides into lens holder over illumination screen and marking plate.

2) Marking plate
Legends are easily printed or engraved on the acrylic resin plate, available in both clear and translucent white.

3) Illumination screen
Supplied in one, two, three or four bits and five colors, red, blue, green amber and white.

4) Light barrier
Divides the illumination areas in the lamp housing to assure proper light projection.

5) Lens holder
Made of stainless steel, contains lamp holder, light barriers, illumination screens, marking plate and front lens.

6) Lamp
Uses midget flanged sub-miniature lamps. Available in 6V, 14V, 28V.

7) Lamp holder
Molded of fiber glass reinforced nylon plastic, it also serves to conduct the pushbutton operation into the contact control mechanism.

8) Leaf spring
Stainless steel, riveted to body, securely holds unit to panel.

9) Housing
Bluish grey non-breakable polycarbonate is standard. Black is also available.

10) Micro switch
Precision, long life, snap-action Burgess V4T6 sub-miniature micro switches. The terminals are designed to accept quick connect terminal sockets and also be soldered.

11) Insulation sheet
Silicon rubber fiber glass, heat resistant and weatherproof. Separates switch and lamp terminals.

12) Magnetic coil leads
Leads from magnetic coil (if fitted) are situated conveniently near to the switch terminals.

FIGURE 1

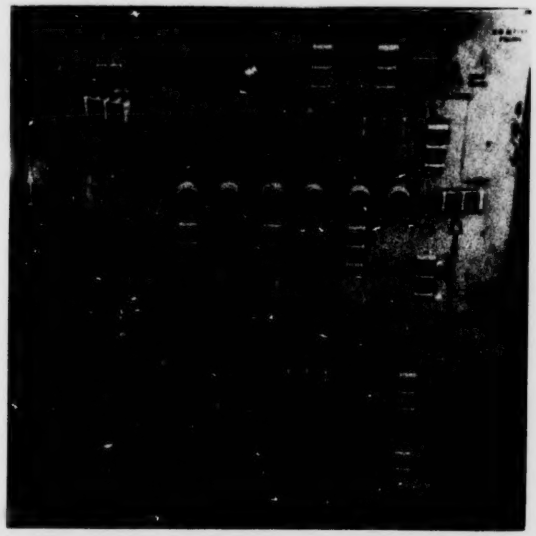


PHOTO 1 Pump room valve mimic panel (port side).

PHOTO 2 Tank valve mimic panel (port side).

PHOTO 3 Tank valve mimic panel (starboard).

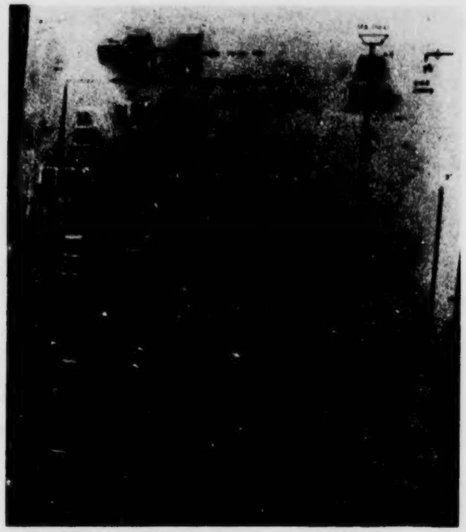


PHOTO 4 Pump room valve mimic panel (starboard).

PHOTO 5 Switch P-19 showing sparking damage.

PHOTO 6 Bottom view of pump room valve mimic panel (port side).

PHOTO 7 Bottom view of tank valve mimic panel (port side).

PHOTO 8 Bottom view of tank valve mimic panel (starboard).

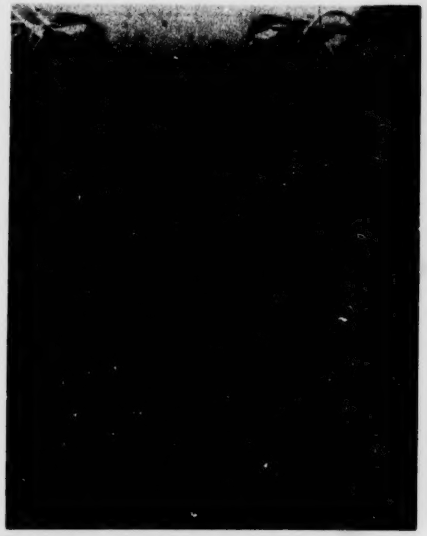


PHOTO 9 Bottom view of pump room valve mimic panel (starboard).

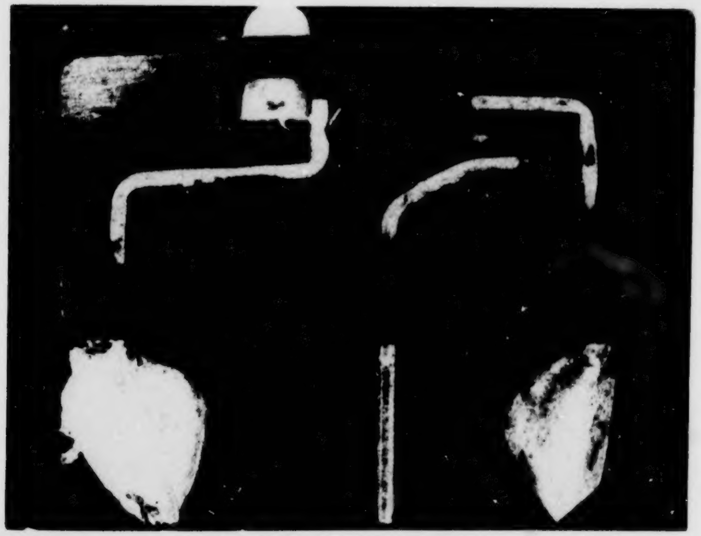


PHOTO 10 Micro switch *Burgess V4T6* revealing interior mechanism and contacts.

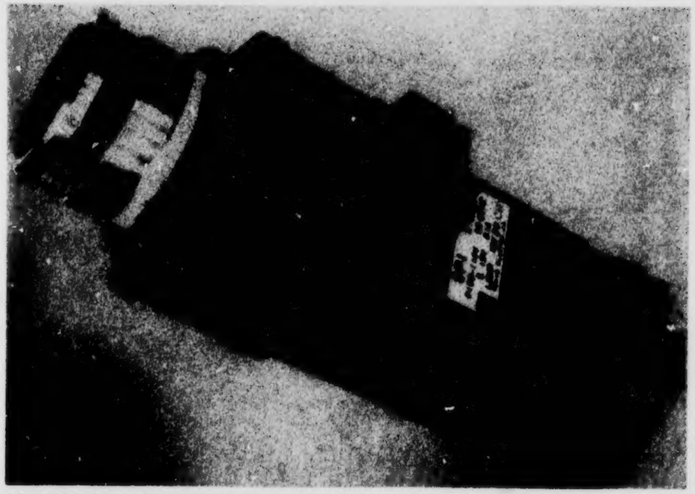


PHOTO 11 Pump switch *red*.

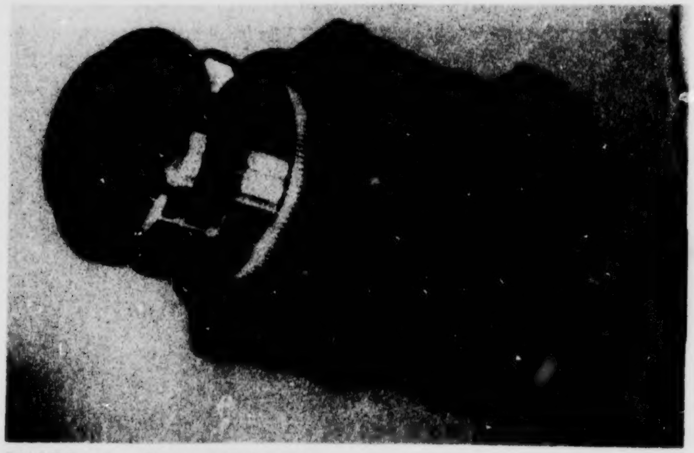


PHOTO 12 Pump switch *green*.

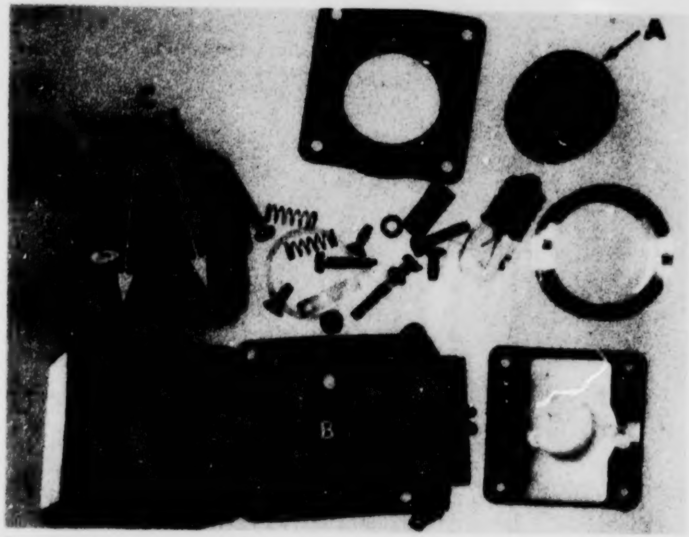


PHOTO 13 Pump switch components showing *A* push button, *B* transformer and *C* switch contacts.

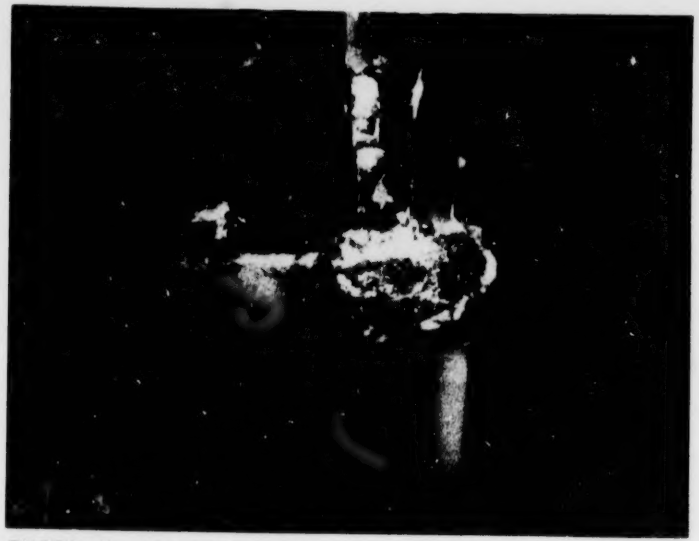


PHOTO 14 Detail of burned area on switch P-19.

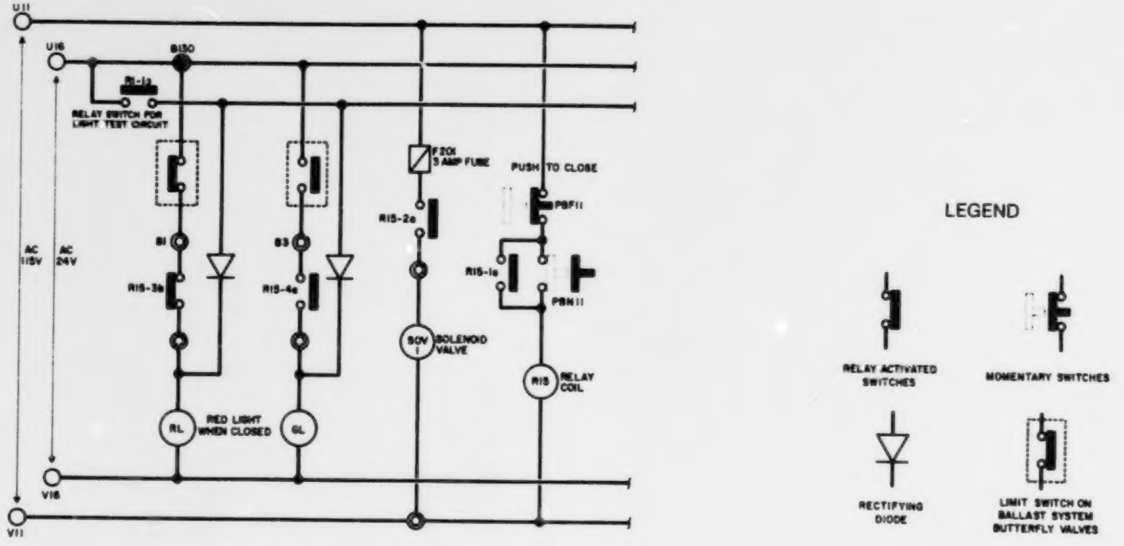
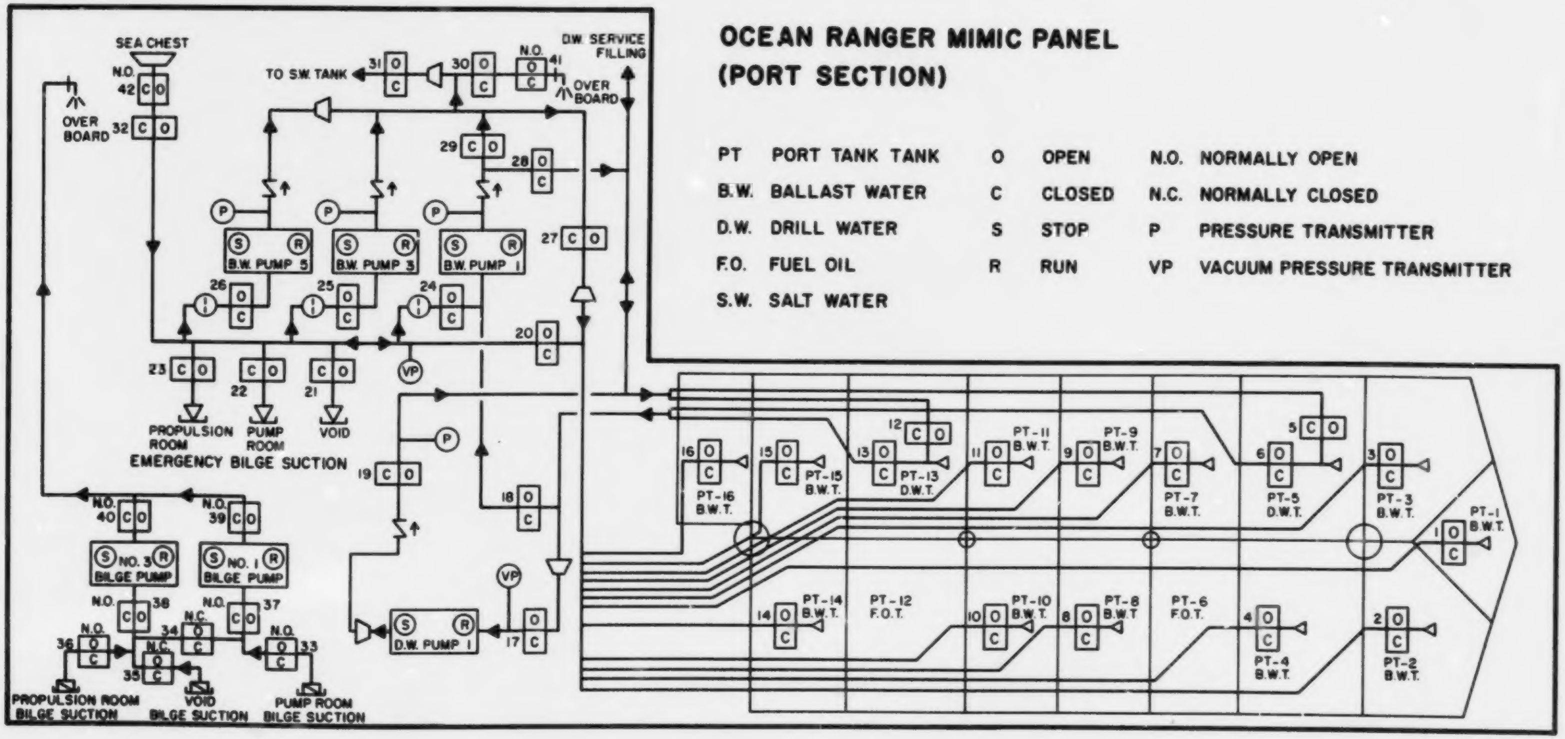

U11
U16
B130
RI-1a
RELAY SWITCH FOR LIGHT TEST CIRCUIT
AC 115V
AC 24V
B1
RI5-3a
B3
RI5-4a
RL
RED LIGHT WHEN CLOSED
GL
F201 3 AMP FUSE
RI5-2a
SOV 1
SOLENOID VALVE
PUSH TO CLOSE
PBF11
RI5-1a
PBN11
RI5
RELAY COIL
V16
V11
LEGEND
RELAY ACTIVATED SWITCHES
MOMENTARY SWITCHES
RECTIFYING DIODE
LIMIT SWITCH ON BALLAST SYSTEM BUTTERFLY VALVES

FIGURE 2



OCEAN RANGER MIMIC PANEL
(PORT SECTION)

PT	PORT TANK TANK	O	OPEN	N.O.	NORMALLY OPEN
B.W.	BALLAST WATER	C	CLOSED	N.C.	NORMALLY CLOSED
D.W.	DRILL WATER	S	STOP	P	PRESSURE TRANSMITTER
F.O.	FUEL OIL	R	RUN	VP	VACUUM PRESSURE TRANSMITTER
S.W.	SALT WATER				

SEA CHEST
N.O. 42
OVER BOARD
32
TO S.W. TANK
31
30
N.O. 41
D.W. SERVICE FILLING
OVER BOARD
29
28
27
B.W. PUMP 5
B.W. PUMP 3
B.W. PUMP 1
26
25
24
20
23
22
21
PROPULSION ROOM
PUMP ROOM
VOID
EMERGENCY BILGE SUCTION
19
18
17
D.W. PUMP 1
N.O. 40
N.O. 39
NO. 3 BILGE PUMP
NO. 1 BILGE PUMP
N.O. 38
N.O. 37
N.O. 36
N.C. 35
N.C. 34
N.O. 33
PROPULSION ROOM BILGE SUCTION
VOID BILGE SUCTION
PUMP ROOM BILGE SUCTION
PT-16 B.W.T.
PT-15 B.W.T.
PT-14 B.W.T.
PT-13 D.W.T.
PT-12 F.O.T.
PT-11 B.W.T.
PT-10 B.W.T.
PT-9 B.W.T.
PT-8 B.W.T.
PT-7 B.W.T.
PT-6 F.O.T.
PT-5 D.W.T.
PT-4 B.W.T.
PT-3 B.W.T.
PT-2 B.W.T.
PT-1 B.W.T.

FIGURE 3

OCEAN RANGER MIMIC PANEL
(STARBOARD SECTION)

ST	STARBOARD TANK	O	OPEN	N.O.	NORMALLY CPEN
B.W.	BALLAST WATER	C	CLOSED	N.C.	NORMALLY CLOSED
D.W.	DRILL WATER	S	STOP	P	PRESSURE TRANSMITTER
F.O.	FUEL OIL	R	RUN	VP	VACUUM PRESSURE TRANSMITTER
S.W.	SALT WATER				

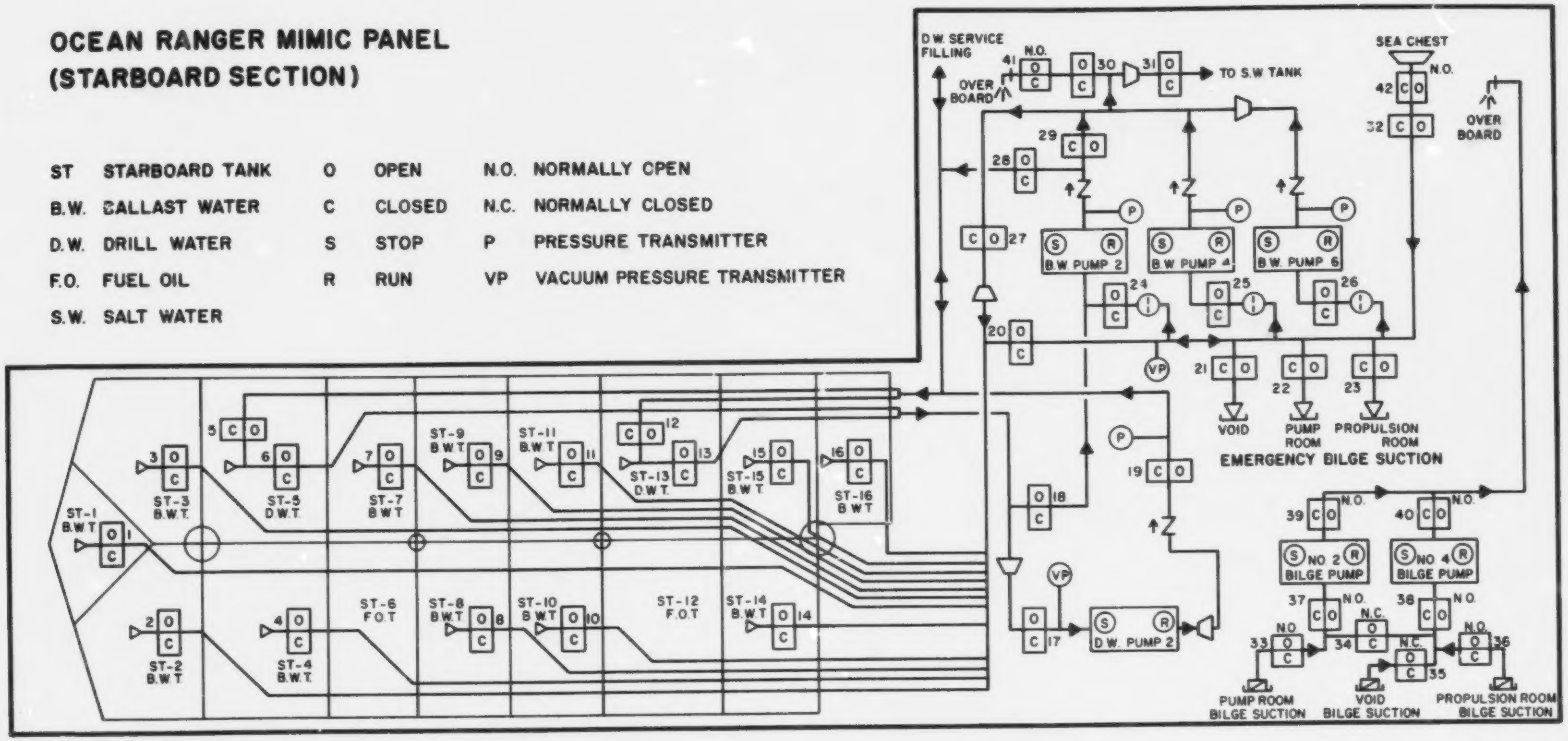

D.W. SERVICE FILLING
OVER BOARD
N.O.
TO S.W TANK
SEA CHEST
OVER BOARD
B.W. PUMP 2
B.W. PUMP 4
B.W. PUMP 6
VP
P
VOID
PUMP ROOM
PROPULSION ROOM
EMERGENCY BILGE SUCTION
NO 2 BILGE PUMP
NO 4 BILGE PUMP
N.C.
D.W. PUMP 2
PUMP ROOM BILGE SUCTION
VOID BILGE SUCTION
PROPULSION ROOM BILGE SUCTION
ST-1 B.W.T
ST-2 B.W.T
ST-3 B.W.T.
ST-4 B.W.T.
ST-5 D.W.T.
ST-6 F.O.T
ST-7 B.W.T
ST-8 B.W.T
ST-9 B.W.T
ST-10 B.W.T
ST-11 B.W.T
ST-12 F.O.T
ST-13 D.W.T.
ST-14 B.W.T
ST-15 B.W.T.
ST-16 B.W.T
O
C
S
R

FIGURE 4

REPORT "E"
ENGINEERING REPORT EP 332/83
BALLAST CONTROL PANEL LIGHT BULB ANALYSIS
8 September 1983

INTRODUCTION

1.1 The Royal Commission investigating the *Ocean Ranger* Marine Disaster requested the Aviation Safety Engineering (ASE) Facility, of the Aviation Safety Bureau, Transport Canada to assist in the investigation by conducting certain tests and analyses on the light bulbs which were removed from the *Ocean Ranger* control panel to determine which bulbs remained functional and which bulbs had experienced damage.

EXAMINATION

2.1 For purposes of analysis, the light bulbs from the control panel were divided into four groups: the port side valve light bulbs labelled P1 through P42, the starboard side valve light bulbs S1 through S42, the port pump lights and the starboard pump lights. The port and starboard valve lights numbered 1 to 42 are housed in switch or indicator assemblies that have a capacity of four bulbs each. Most of the assemblies contained only two bulbs each. one to illuminate the red translucent function plate "closed" and one to illuminate the green translucent plate "open". In the assemblies that contained more than two bulbs only two were wired into the circuit. Therefore the extra bulbs were not examined as part of the system. The port and starboard pump lights indicated which pumps were running by illuminating a green bulb while a red button indicated a stopped pump. The switch assemblies were wired for 24 volts to power the light bulbs and a 115 volt circuit ran alongside the 24 volt circuit to power the valve solenoids. The valve lights numbered 33 to 42 were manual valve indicator lights without switches, and were wired for 24 volts only.

2.2 The bulbs found on the panel were manufactured by various companies (Stanley and Chicago Miniature were most common) and were typically type 387. All of the bulbs found were considered acceptable for use in this application.

2.3 Examination of the bulbs included an optical microscopic evaluation of all filaments. This examination revealed that

TABLE 1

Valve Lights – Port and Starboard

SWITCH	COMMENTS
P3 Open	Fracture – Hot.
P3 Closed	Filament fused to glass in three locations, broken in three places.
P4 Open	Broken hot in one location and fused to glass.
P4 Closed	Broken hot and fused to glass.
P5 Closed	Broken hot and fused to glass in two places.
P6 Open	Broken hot and fused to glass.
P7 Open	Support posts and filament through glass.
P11 Closed	Filament fused to glass.
P12 Closed	Broken hot and fused to glass.
P13 Closed	Broken hot several fragments. Burnout due to combination of age and excessive voltage.
P14 Closed	Broken hot and fused to glass.
P15 Open	Brittle fracture.
P16 Closed	Broken hot and slight fusing.
P19 Closed	Broken hot filament.
P20 Open	Broken from each contact post. Failure probably hot.
P20 Closed	Broken near contact post. Failure probably hot.
P25 Open	(Data not included)
P25 Closed	Filament broken hot. Evidence of melt spots on filament and one brittle fracture.
P27 Closed	Broken hot.
P28 Closed	Filament through glass and support post through glass. Possible burnout.
P28 Open	Filament broken loose inside brittle failures.
P29 Open	Filament broken brittle and fusing.
P31 Open	Filament broken hot.
P33 Open	Broken hot near support post.
P34 Closed	Broken hot.
P35 Open	Broken hot, portions fused to glass envelope.
P35 Closed	Broken hot, pieces fused to glass.
P36 Closed	Broken hot between support posts.
P37 Open	Broken hot.
P38 Open	Several fragments of filament hot.

several of the light bulbs contained fractured filaments, Photo 1 and/or stretched filaments, Photo 2 and/or filaments fused to the glass envelope, Photo 3. All of the bulbs with any type of damage were subsequently examined in the Scanning Electron Microscope (SEM). In most cases of fractured filaments, the filament was broken near its contact post, which is an inherently weak spot in light bulb filaments. SEM analysis of the fracture surfaces revealed that most of the failures exhibited a smooth fracture surface, characteristic of a hot filament at the time of failure, except for eight of the fractures which appeared brittle. Photos 4, 5 and 6 show "hot" fractures or smooth fracture surfaces typical of those found in the *Ocean Ranger*. Table 1 contains a list of all of the bulbs examined that exhibited damage.

DISCUSSION

3.1 The "hot" fractures observed in nearly all of the broken filaments can typically occur as a result of three different mechanisms:

a) severe impact while incandescent;
b) burnout due to old age;
c) burnout due to over-voltage.

The fact that 43 percent of the bulbs failed and that no substantial impact would be expected to have occurred during the rig's sinking suggests that the bulbs were burned out due to over-voltage. Laboratory tests of General Electric type 327 bulbs (similar to the bulbs found in the *Ocean Ranger*) were carried out to determine the effects of high voltage. These tests revealed that the filaments fractured typically near one or both of the contact posts and the filament often fused to the glass envelope. The fracture surfaces were typically smooth and similar to those found in the *Ocean Ranger* control panel. The majority of the bulbs examined from the *Ocean Ranger* did not show signs of excessive age (severe notched appearance) which ruled out burning due to old age. High voltages in tests also caused areas of local filament stretch and as voltage levels were increased, the failures became more explosive, with filaments coming to rest fused to the glass envelope.

3.2 A simulation of the starboard side control panel shown in Photo 7 containing new General Electric type 327 bulbs was flooded with sea water to simulate observed damage to the control panel. The 24 volt circuit fuse blew shortly after and all the lights went out. After some time, lights began to flash

TABLE 1 – (CONT'D)

Valve Lights – Port and Starboard

SWITCH	COMMENTS
P41 Open	Broken hot.
P42 Open	Broken hot and aged.
S2 Closed	Filament fused to glass, water present, severely corroded.
S3 Closed	Filament broken. Support post fused to glass.
S5 Open	Filament broken and fused to glass. Failure looks brittle.
S8 Closed	Filament broken hot. Support touching glass. Evidence of local melting.
S13 Closed	Broken hot.
S14 Open	Possible burnout. Not fracture but stretch.
S14 Closed	Support posts fused. Hot fracture.
S15 Closed	Broken filament hot fused to glass.
S16 Closed	Evidence of local melting, fracture.
S17 Open	Broken hot.
S18 Closed	Broken hot.
S20 Open	Broken filament hot. Posts fused to glass.
S21 Closed	Broken hot.
S22 Closed	Broken hot.
S25 Closed	Broken hot. Fused to glass.
S28 Closed	Broken hot and one brittle fracture. Possible burnout.
S29 Open	Broken hot local melting.
S29 Closed	Broken hot and fused. Local melting.
S30 Closed	Broken hot and fused. Brittle failure found.
S31 Closed	Broken hot and fused.
S32 Open	Broken brittle and fused.
S32 Closed	(Data not included)
S33 Open	Broken hot.
S34 Open	Broken hot.
S34 Closed	Broken hot.
S37 Open	Broken hot.
S37 Closed	Broken hot.
S38 Open	Broken hot.
S39 Open	Broken hot.

on randomly with varying high intensity. Of the bulbs examined in the simulation panel approximately 80% revealed damage characteristic of a burnout due to over-voltage. Photos 8 and 9 show filaments from the simulation panel. Photo 8 shows filament stretch similar to that shown in Photo 2 from the actual panel. Photo 9 shows local enlargement of the filament cross section similar to the over-voltage test results depicted in Photo 10 and similar to Photo 4 of the actual panel. Local enlargement of the filament wire near the fracture was not as apparent in the actual *Ocean Ranger* bulbs, possibly because of the age of the filaments. It is possible that the 24 volt circuit blew and the 115 volt circuit arced with the aid of the water, causing the bulbs to see voltages well in excess of 24 volts in the actual *Ocean Ranger* panel as well as in the simulation panel. The light bulbs listed in Table 1 were probably subjected to voltage surges well in excess of 24 volts.

CONCLUSIONS

4.1 The light bulbs were considered to be standard light bulbs for this type of application on a 24 volt circuit.

4.2 The 76 bulbs listed in Table 1 appear to have suffered heat damage, probably due to voltage surges well in excess of 24 volts.

4.3 Eight of the bulbs in Table 1 contained both brittle fractures and evidence of fusing and melting, and were considered burned out also.

4.4 Twenty-three of the bulbs contained filaments and/or support posts fused to the glass envelope indicative of over-voltage or intense heat.

4.5 Figures 1 and 2 are diagrams of the *Ocean Ranger* panel showing the bulbs that were considered to be damaged due to over-voltage and Figure 3 contains a diagram of the simulation panel (starboard panel only) showing the bulbs that were damaged due to over-voltage.

TABLE 1 (CONT'D)

Pumplights—Starboard

SWITCH	COMMENTS
#2 B.W. STOP	Filament fused to glass.
#4 B.W. STOP	Aged and broken hot.
#6 B.W. RUN	Aged and broken hot.
#2 BILGE STOP	Aged broken hot.
#4 BILGE STOP	Aged broken hot.
#2 DRILL STOP	Broken hot.
S39 Closed	Broken hot.
S41 Open	Broken hot.
S42 Open	Broken hot.

Pumplights – Port

SWITCH	COMMENTS
#1 B.W. STOP	Aged and broken hot.
#3 B.W. STOP	Aged and broken hot.
#5 B.W. STOP	Fused and broken hot.
#1 BILGE STOP	Aged and broken hot.
#3 BILGE STOP	Aged and broken hot.
#1 D.W. STOP	Aged and broken hot.

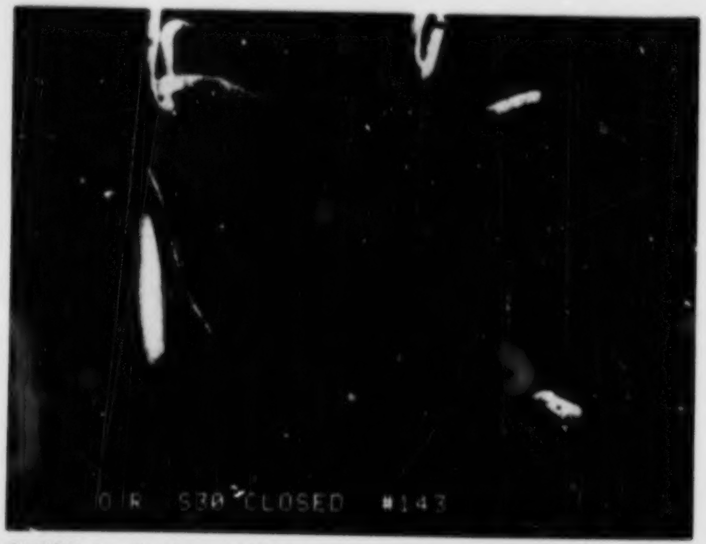

0 R S30 CLOSED #143

PHOTO 1 Starboard #30 closed. Filament broken near contact post.

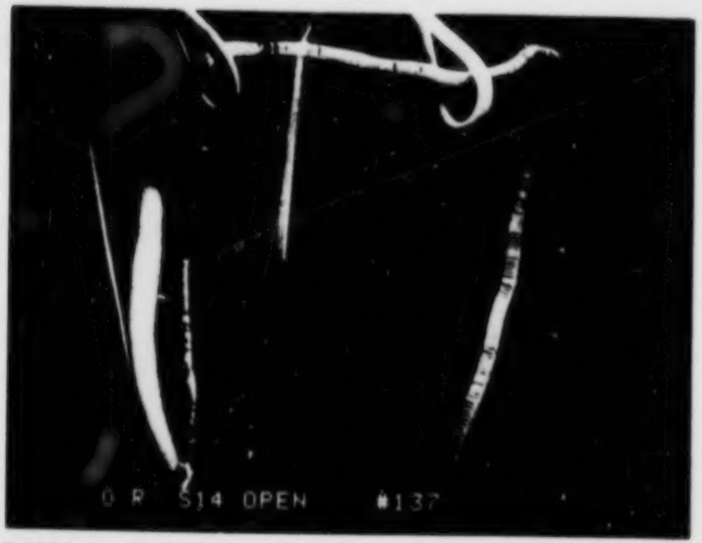

0 R S14 OPEN #137

PHOTO 2 Stretched filament damage probably due to high voltage.

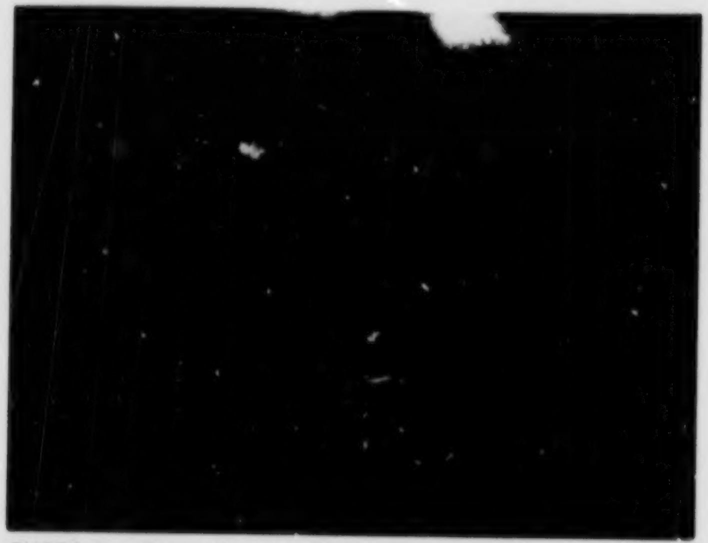


PHOTO 3 Filament fused to glass from #2 bilge water starboard *stop* pumplight.

P38 OPEN #113

PHOTO 4 Hot fracture of port #38 open bulb.

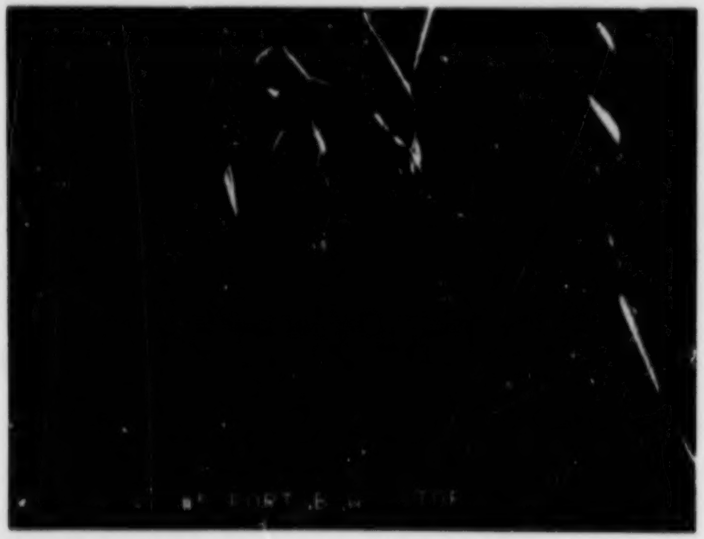


PHOTO 5 Smooth fracture surface of port ballast water stop bulb.

PHOTO 6 Smooth fracture surface of port #3 ballast water stop.

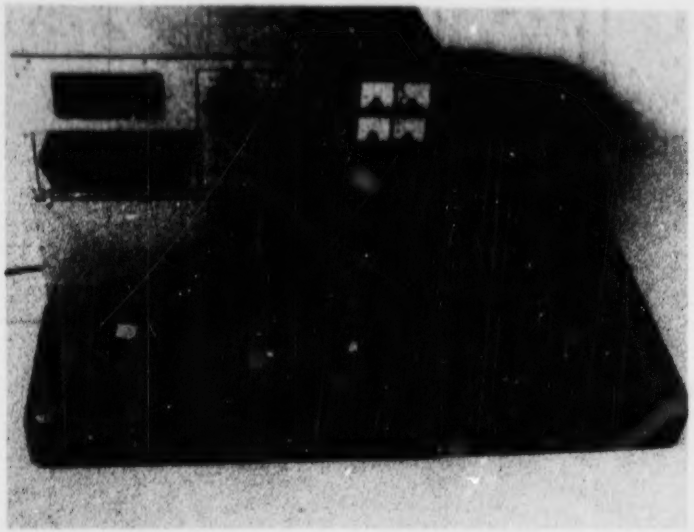


PHOTO 7 Simulation control panel of the *Ocean Ranger*.

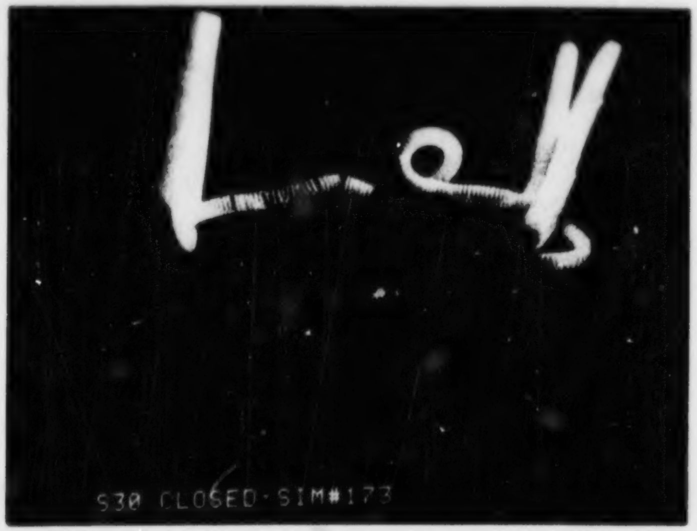


PHOTO 8 Filament from simulation panel flooded with water.

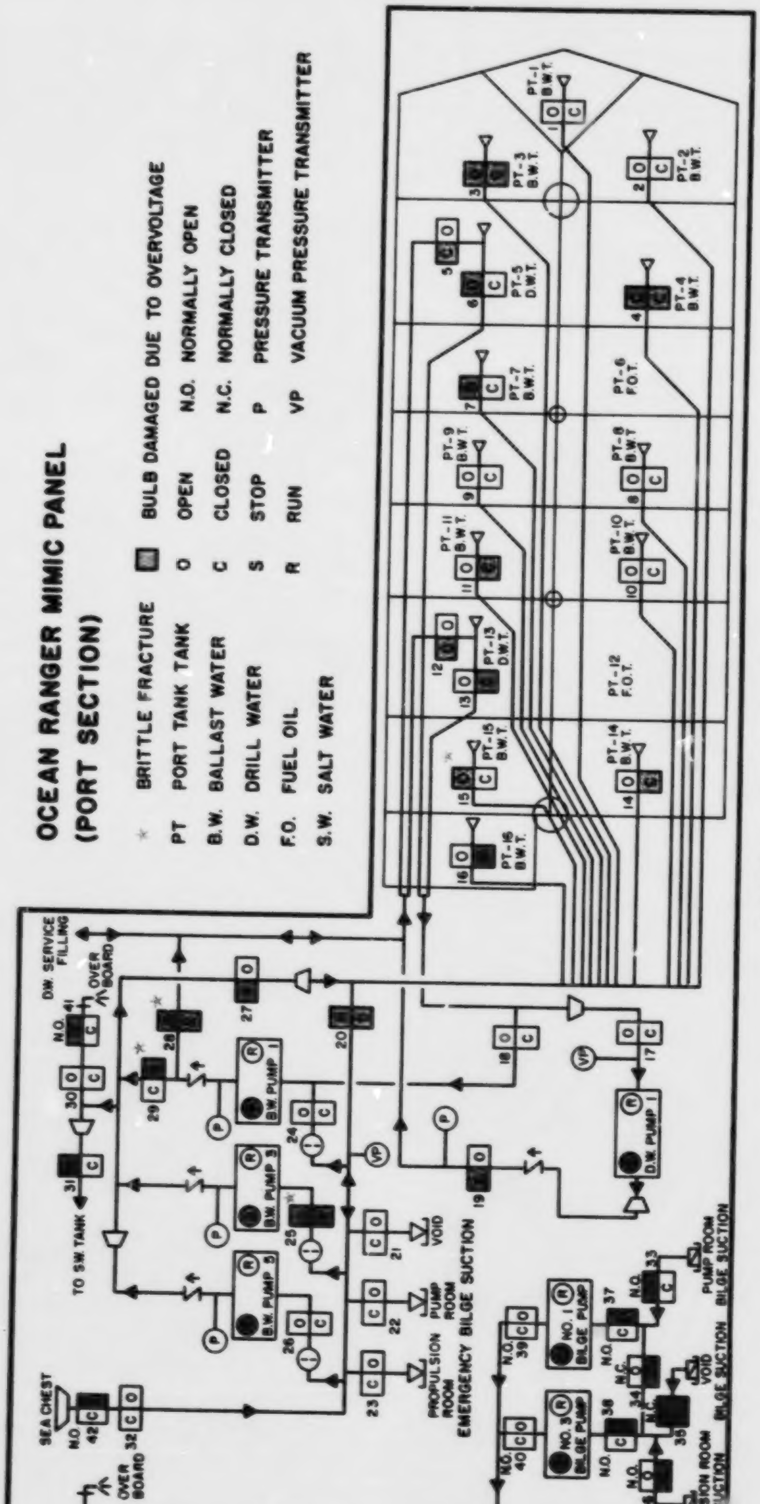
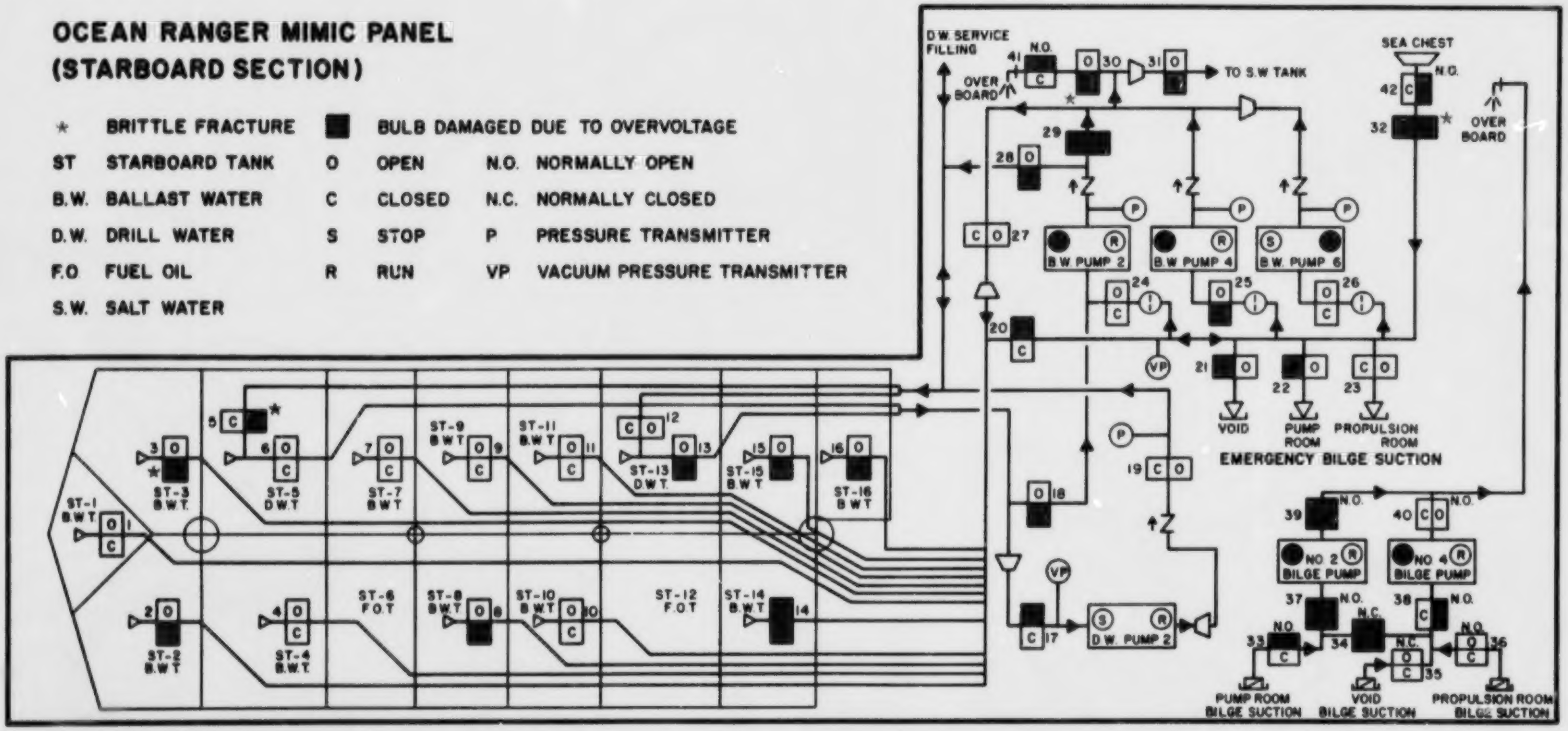

OCEAN RANGER MIMIC PANEL
(PORT SECTION)
* BRITTLE FRACTURE
PT PORT TANK TANK
B.W. BALLAST WATER
D.W. DRILL WATER
F.O. FUEL OIL
S.W. SALT WATER
▨ BULB DAMAGED DUE TO OVERVOLTAGE
O OPEN
C CLOSED
S STOP
R RUN
N.O. NORMALLY OPEN
N.C. NORMALLY CLOSED
P PRESSURE TRANSMITTER
VP VACUUM PRESSURE TRANSMITTER
PT-1 B.W.T.
PT-2 B.W.T.
PT-3 B.W.T.
PT-4 B.W.T.
PT-5 D.W.T.
PT-6 F.O.T.
PT-7 B.W.T.
PT-8 B.W.T.
PT-9 B.W.T.
PT-10 B.W.T.
PT-11 B.W.T.
PT-12 F.O.T.
PT-13 D.W.T.
PT-14 B.W.T.
PT-15 B.W.T.
PT-16 B.W.T.
D.W. SERVICE FILLING
OVER BOARD
TO S.W. TANK
SEA CHEST
B.W. PUMP 1
B.W. PUMP 3
B.W. PUMP 5
D.W. PUMP 1
NO. 1 BILGE PUMP
NO. 3 BILGE PUMP
VOID
PUMP ROOM
PROPULSION ROOM
EMERGENCY BILGE SUCTION
PUMP ROOM BILGE SUCTION
VOID BILGE SUCTION
PROPULSION ROOM BILGE SUCTION

FIGURE 1 Port Mimic Panel.

OCEAN RANGER MIMIC PANEL (STARBOARD SECTION)



*	BRITTLE FRACTURE	■	BULB DAMAGED DUE TO OVERVOLTAGE		
ST	STARBOARD TANK	O	OPEN	N.O.	NORMALLY OPEN
B.W.	BALLAST WATER	C	CLOSED	N.C.	NORMALLY CLOSED
D.W.	DRILL WATER	S	STOP	P	PRESSURE TRANSMITTER
F.O	FUEL OIL	R	RUN	VP	VACUUM PRESSURE TRANSMITTER
S.W.	SALT WATER				

D.W. SERVICE FILLING
OVER BOARD
TO S.W TANK
SEA CHEST
OVER BOARD
B.W. PUMP 2
B.W. PUMP 4
B.W. PUMP 6
D.W. PUMP 2
VOID
PUMP ROOM
PROPULSION ROOM
EMERGENCY BILGE SUCTION
NO. 2 BILGE PUMP
NO 4 BILGE PUMP
PUMP ROOM BILGE SUCTION
VOID BILGE SUCTION
PROPULSION ROOM BILGE SUCTION
ST-1 B.W.T
ST-2 B.W.T
ST-3 B.W.T.
ST-4 B.W.T
ST-5 D.W.T
ST-6 F.O.T
ST-7 B.W.T
ST-8 B.W.T
ST-9 B.W.T
ST-10 B.W.T
ST-11 B.W.T
ST-12 F.O.T
ST-13 D.W.T.
ST-14 B.W.T
ST-15 B.W.T
ST-16 B.W.T

FIGURE 2 Starboard Mimic Panel.

PHOTO 9 Filament from simulation panel flooded with water.

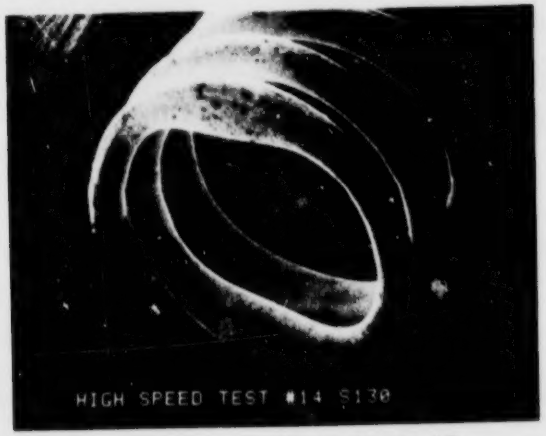

HIGH SPEED TEST #14 S130

PHOTO 10 Filament experiencing 70 volts AC in the laboratory.

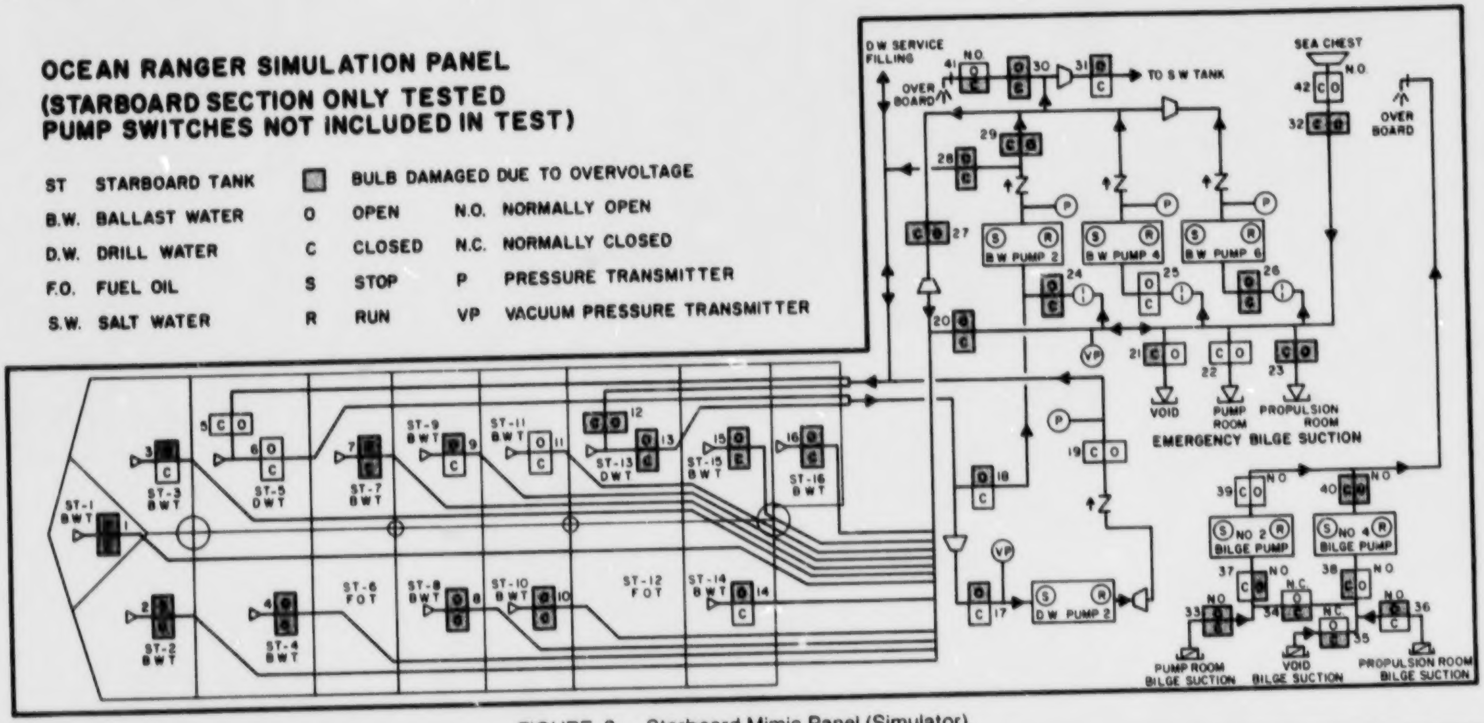

OCEAN RANGER SIMULATION PANEL
(STARBOARD SECTION ONLY TESTED
PUMP SWITCHES NOT INCLUDED IN TEST)
ST STARBOARD TANK
B.W. BALLAST WATER
D.W. DRILL WATER
F.O. FUEL OIL
S.W. SALT WATER
▨ BULB DAMAGED DUE TO OVERVOLTAGE
O OPEN
C CLOSED
S STOP
R RUN
N.O. NORMALLY OPEN
N.C. NORMALLY CLOSED
P PRESSURE TRANSMITTER
VP VACUUM PRESSURE TRANSMITTER
D W SERVICE FILLING
OVER BOARD
TO S W TANK
SEA CHEST
OVER BOARD
B W PUMP 2
B W PUMP 4
B W PUMP 6
VOID
PUMP ROOM
PROPULSION ROOM
EMERGENCY BILGE SUCTION
NO 2 BILGE PUMP
NO 4 BILGE PUMP
D W PUMP 2
PUMP ROOM BILGE SUCTION
VOID BILGE SUCTION
PROPULSION ROOM BILGE SUCTION
ST-1 BWT
ST-2 BWT
ST-3 BWT
ST-4 BWT
ST-5 DWT
ST-6 FOT
ST-7 BWT
ST-8 BWT
ST-9 BWT
ST-10 BWT
ST-11 BWT
ST-12 FOT
ST-13 DWT
ST-14 BWT
ST-15 BWT
ST-16 BWT

FIGURE 3 Starboard Mimic Panel (Simulator).

REPORT "F"
ENGINEERING REPORT EP 333/83
BALLAST CONTROL PANEL TESTS
8 September 1983

INTRODUCTION

1.1 The Royal Commission investigating the *Ocean Ranger* Marine Disaster requested the Aviation Safety Engineering (ASE) Facility of the Aviation Safety Bureau, Transport Canada to assist in the investigation by conducting certain tests and analyses on a ballast control (mimic) panel and the micro command switches used in these panels to determine the effects of salt-water flowing over the panel and entering the switches.

TEST EQUIPMENT

2.1 A control panel "Simulator" was constructed as depicted in Photo 1. It consisted of the two starboard mimic panels recovered from the rig mounted at a slant of 12° on 18 cm height boxes, see Photos 2 and 3, and a "Display and Monitoring Panel" mounted vertically on a box 80 x 30 x 50 cm in height, Photo 4. The three boxes were bolted together to form the test panel as shown in Photo 1.

2.2 New micro command switches and indicator lights, identical to those from the rig, were obtained and installed in the tank and pump room mimic panels as shown in Photos 2 and 3. The six pump switch pairs were different from those on the rig in that their buttons did not contain lights. The monitoring and display panel, Photo 4, consisted of the following:

1) a mimic panel of 32 green and 32 red lights, see Photo 5, which simulated the actual positions of the butterfly valves; 6 green and 6 red larger lights which simulated actual pump run or stop condition and ten toggle switches simulating the actual manual valve positions;
2) 115 volts main voltage and current meter, see Photo 6;
3) 24 volts voltage and current meters which monitor the lights on the mimic panel;
4) main switch and fuses;
5) relay fuses;
6) switch panel power supply fuses;
7) light test switch simulating the lamp test relay in the original panel.

The two stainless steel mimic panels were directly connected to ground for safety.

2.3 The wiring of the switches and indicator lights on the mimic panel was identical to that on the panels of the rig. However the components that were controlled via the panel, such as control valves, butterfly valve and pumps, were replaced by relays, lights and switches in the display panel. The solenoid control valves were replaced by relays, and the limit switches on the butterfly valve pistons were replaced by these relay contacts and lights showing their open and closed position. The manual valves were simulated by toggle switches and pumps by red and green indicator lights. The basic wiring diagram is shown in Figure 1.

2.4 The ballast control panel was designed to operate as follows:

1) when connected to an 115 volt AC supply and switches on, all 32 red lights on the switches and the 32 red butterfly valve lights on the display panel were lit. The manual valve indication lights 33 to 42 on the panel were lit red or green as a function of the toggle switches' position on the display panel;
2) the pump lights were also lit as a function of the pump switch positions on the panel. The meters indicated the main voltage and current and the voltage and current of the mimic panel lamp circuit.

2.5 When the light test switch is thrown, all non-lit lights light up at half power. This test serves as a check as to whether any light has burned out.

2.6 When a micro command switch green button is depressed the adjacent red light will go out and subsequently the green light will go on. The same thing will happen to the corresponding light on the display panel. On the rig, where a large butterfly valve had to open completely, there is a period of about 30 seconds duration when both red and green lights are off, which is an indication that the butterfly valve is "in transit".

2.7 The command switches and relays on the rig were wired in such a manner that a short circuit in the green switch could only open the control valve while a short circuit in the red switch could *not* close the valve. The test control panel was wired in a similar manner except that the corresponding green light on the display panel would light.

2.8 The switch indication lights' circuit was monitored by a voltage meter, an ampere meter and two ten ampere fuses. Since the test panel simulated only the starboard side, the fuses were half the value of the 20 ampere fuses used on the *Ocean Ranger*.

TESTING

3.1 The intent of the test was to apply a quantity of sea water over the ballast control mimic panel and to observe the effects. The tests were performed at the Engineering Facilities of Memorial University, St. John's, Newfoundland.

3.2 Appropriate scaffolding and a 50 gallon capacity trough was constructed to douse the panel with sea water in a manner similar to how it was believed to have occurred on the night of the capsizing. Photo 7 shows the test set-up just before the test.

3.3 Fifty gallons of sea water were poured on the panel over a three second period while all valve and switch lights were red. The observed effects were immediate. The 24 volt mimic panel light circuit fuse blew. On checking the blown fuse it was discovered that it was a five ampere fuse instead of the intended ten ampere fuse. The fuse was replaced with a ten ampere fuse which also blew after a few minutes. The fuse blew as a result of salt-water entering most of the switch lamp housings shorting out the lights and causing an increased load on the circuit.

3.4 Within minutes ten valve lights on the display panel turned to green, indicating that water had entered the microswitch and shorted it out. Most of these ten green lights did not go out during the one hour test period. The ten green lights corresponded to switch numbers: 1, 10, 18, 19, 21, 23, 25, 26, 28, and 30.

3.5 During the one hour test period that the power was left on the panel, most of the lights (typically one or two randomly distributed at a time) would flicker and light up very brightly momentarily and then die out. Also sparking was heard continuously, but also randomly distributed over the panel, as was the observation of smoke coming from the switches. At one point, one switch housing even caught fire. After about an hour it was decided to cut the power, since the damage observed was much more extensive than that observed on the *Ocean Ranger* ballast control panels.

TEST RESULTS

4.1 After the power was cut, some switches were removed from the panel and it was noted that the burning damage was similar to, but more extensive than, the damage observed on switch P-19 of the *Ocean Ranger* panel.

4.2 Analysis of the switches determined that shorts created by sea water between the 115 volt circuit and ground (via the leaf spring and the panel) caused more sparking, which provided sufficient heat energy to burn and melt the plastic housing of the switch.

4.3 The 115 volt circuit also leaked in a similar manner into the 24 volt circuit, causing the same burning damage on the manual valve indicator light housing. The damage to nearly all switches and indicators was severe, as is evident from Photo 8.

4.4 All 84 light bulbs were removed from the switches and indicator lights and microscopically examined for broken filaments. Ten bulbs were found to be relatively undamaged and twelve were too badly damaged by heat for proper examination of the filament, while 62 bulbs were found to have broken filaments with "hot" fractures indicating failure due to over-voltage. The analysis of the *Ocean Ranger* test light bulbs are covered in the Light Bulb Analysis Report "E", (EP 332/83).

DISCUSSION

5.1 The extensive burning damage to the panel switches made it clear that the test scenario sequence contained a basic difference from the actual events in the ballast control room prior to the capsizing of the rig, although shorting of switches and failure of light bulbs did occur as expected. The differences were considered to be due to one or more of the following:

a) the quantity of water used in the test did not compare closely to that flooding the mimic panel in the actual drill rig;
b) whereas in the test, power was left on the panel for a period of one hour, the drill rig crew may have cut power to the mimic panel shortly after the initial water flood;
c) the grounding of the test panel, and the AC polarity used, may not have been identical to that in the drill rig.

5.2 With respect to point (a) of Paragraph 5.1, the quantity of water used in the test was decided on the basis that a wave large enough to burst the porthole glass must have driven large quantities of water in the control room, of which a substantial part must have flooded the panel. The light bulb failures on the actual control panels were relatively evenly distributed, as is evident from report "E", (EP 332/83). This is evidence that water covered all areas of the panel, even around obstructions such as the upper part of the console, indicating that substantial quantities of water must have flowed over the panel.

5.3 With respect to point (b) of Paragraph 5.1, from communications it was known that the crew made a mopping-up effort after the bursting of the porthole. Circuit breaker NFB1, located behind the left-hand door in the upper part of the console, may have been pulled during the clean-up. A report that all systems were functioning normally again was put out around 22:00 hrs.

5.4 With respect to point (c) of Paragraph 5.1, when the test panel was constructed it was assumed that the stainless steel mimic panels should be grounded. This grounding provided the electrical pass for the sea water shorted sparking, which caused all the damage not generally observed on the *Ocean Ranger* panel switches (except for Switch P-19). Lack of grounding of the test panel would most likely have prevented this damage. It should be noted that no reference to grounding was found in any of the electrical schematics. It was also considered possible that all switches were wired to the neutral line of the 115 volt AC supply on the panels. If this was the case, then "shorting" to ground of the neutral line on the *Ocean Ranger* panel would not have created a potential and therefore no sparking damage would have occurred. The hot line of the 115 volt supply would then pass through the relay coil before being connected to the switch terminal. Shorting of this line to ground could have possibly energized the relay in an irregular manner, causing red lights to "flicker". In this configuration a short between the 24 volt circuit and the 115 volt hot line which passed through the relay coil first could still cause over-voltage in the light bulbs and burn them out.

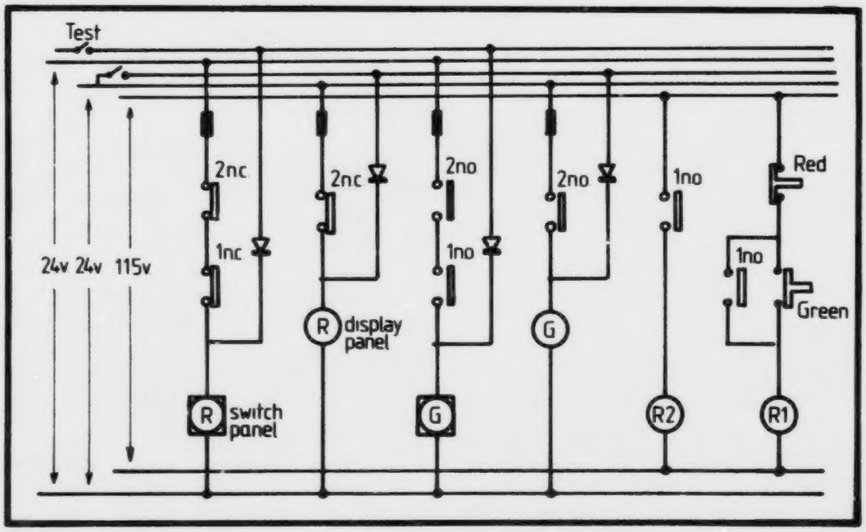


FIGURE 1 Basic Test Panel Schematic

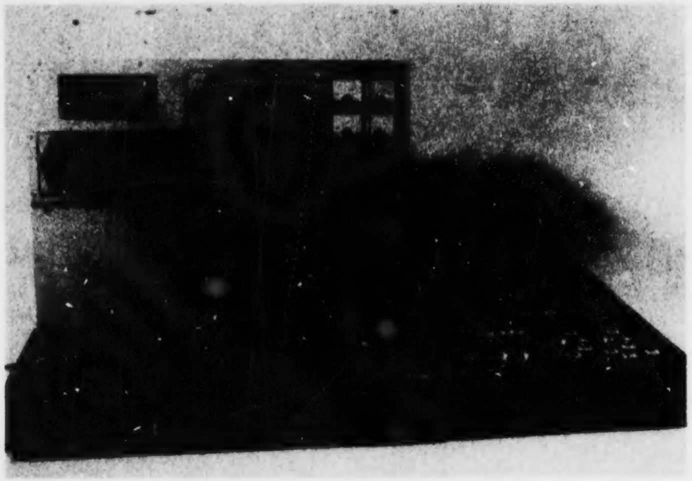


PHOTO 1 Complete Test Panel

PHOTO 2 Starboard Tank Valve Switch Mimic Panel

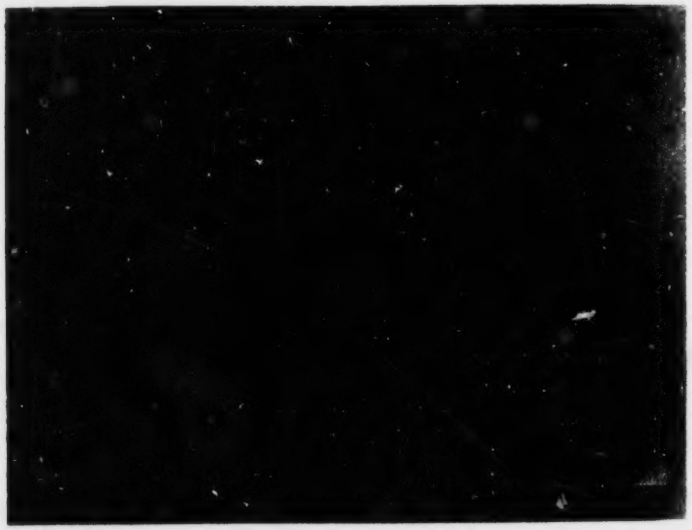


PHOTO 3 Starboard Pump Room Valves Switch Mimic Panel

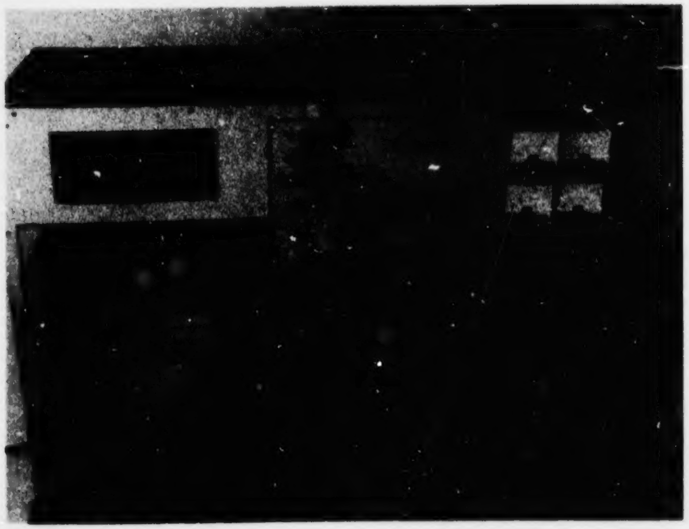


PHOTO 4 Display Panel

PHOTO 5 Display Mimic Panel

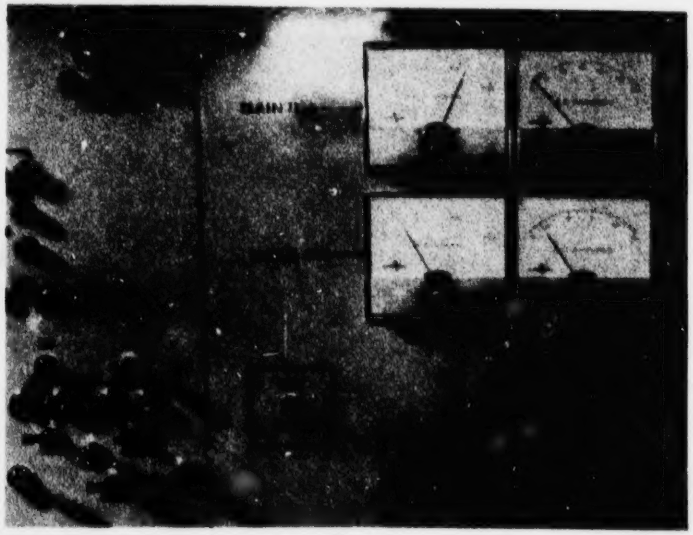


PHOTO 6 Meter and Fuse Panel

PHOTO 7 Panel set-up just prior to test.

PHOTO 8 Micro command switch showing arcing damage after test.

REPORT "G"
ENGINEERING REPORT 195/82
BALLAST CONTROL ELECTRICAL SYSTEM AND OVERALL ANALYSIS
8 September 1983

INTRODUCTION

1.1 The Royal Commission investigating the *Ocean Ranger* Marine Disaster requested the Aviation Safety Engineering (ASE) Facility, of the Aviation Safety Bureau, Transport Canada to assist in the investigation by conducting certain tests and analyses on the ballast control room portholes, the ballast control (mimic) switch panels and the ballast control solenoid valves.

1.2 Three portholes, four switch panels and six valve banks were forwarded to ASE with the following list of requests:

1) prior to analysis and testing, photograph and identify all portholes, control valves, switches and indicator lights;
2) determine the mode of failure of two portholes with broken glass;
3) pressure test the undamaged porthole to determine wave force required to fail the glass;
4) examine all control valves for evidence of possible manual operation;
5) determine significance of presence or absence of the rubber plugs on the solenoid valves housing;
6) determine the valve positions of the 18 valves found with manual actuator rods inserted;
7) examine all switches for evidence of burning or arcing to terminals and contacts;
8) examine all indicator lights for evidence of burning, arcing and light bulb failure;
9) determine mode of all light bulb failures;
10) analyse the switches and indicator lights in terms of their susceptibility to salt-water damage;
11) determine the effects of salt-water flow over the control panel to the ballast control system through testing on a reconstructed ballast control panel;
12) analyse the ballast control electrical system in terms of safety, reliability and susceptibility to salt-water damage and electrical failure.

1.3 The Royal Commission Counsel provided ASE with the following information related to the accident:

1) on 14 February at approximately 19:30 hours a porthole in the ballast control room was reportedly smashed by a wave and quantities of water entered the control room;
2) the crew reported that the influx of sea water had affected the ballast control panels and that a cleaning operation was in progress;
3) around 22:00 hours it was reported that all systems were functioning normally again and that mopping-up was completed;
4) on 15 February at around 01:00 hours a severe and uncontrollable forward list was reported, together with a Distress call.

1.4 After receipt of the ballast control room components and the Royal Commission's requests, ASE divided the necessary work to be performed into the following separate projects:

A – Porthole Analysis
B – Porthole Glass Testing
C – Ballast Control Valve Analysis
D – Ballast Control Panel Switch Analysis
E – Light Bulb Analysis
F – Ballast Control Panel Test
G – Covering Report with Ballast Control Electrical System and Overall Analysis

Each of the projects is covered in a separate report which are assembled in this covering report "G" and will be referenced by their assigned designator letter.

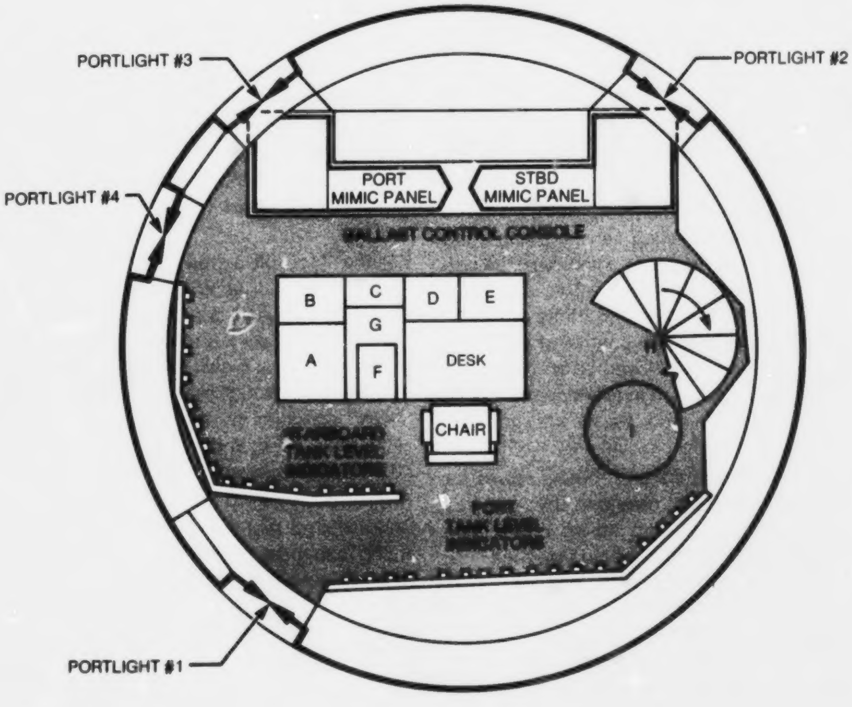


FIGURE 1 Ballast Control Room

A	Hydrophone Control Unit
B	Hydrophone Electronics Panel
C	CO^2 Actuating Cabinet
D	Sliding Door Control
E	Smoke Detection Cabinet
F	Teleprinter
G	Display Terminal
H	Spiral Staircase
I	Watertight Manhole

SYSTEM DESCRIPTION

2.1 The ballast control room was located in the after centre starboard column SC3 about 33 meters above the keel baseline. The room was circular, approximately 5 meters in diameter and could be entered only from above, through a spiral staircase from the upper control room. The room had four portholes located as described in Figure 1 and ASE Report "A", (EP 266/82). The portholes were about 50 cm in diameter and could not be opened, each having a deadlight hinged from the top. The furnishings and equipment layout is also shown in Figure 1.

2.2 The ballast control console was about 3.5 meters wide, 1 meter deep and mostly counter high except for the relay cabinet and meter panel.

2.3 The ballast control console consisted of:

1) service tank level alarm panel;
2) port and starboard watertight alarm panels;
3) port and starboard meter and gauge panels;
4) port and starboard relay and terminal racks;
5) port and starboard control switch mimic panels;
6) port and starboard control valve banks.

Only the control switch mimic panels and the six control valve banks were recovered from the wreckage.

2.4 The ballast control system functioned roughly as follows: in each pontoon, the twelve ballast tanks are connected with butterfly valves to the ballast water manifold which is located in the pump room aft in the pontoon, where routing valves, pumps and piping are located to accommodate the ballast and level requirements. Two drill water tanks can also become part of the system in an emergency and are controlled by a four valve manifold. The "overboard" and "sea chest" each have a manually operated valve for emergencies and these are normally open.

2.5 Thirty-two tanks and routing valves for each pontoon are operated by one-way pneumatic pistons with spring return, and are controlled by the solenoid operated control valves located in the base of the ballast control console. Air supply lines approximately one centimeter in diameter run the air from the control valves to the butterfly valve pistons. The air supply was typically 90 psi, and removal of the air supply would cause all thirty-two pneumatically operated valves to close.

2.6 All butterfly valves, and all the manually operated valves, have limit switches at the extremes of their stroke which control the indicator lights on the ballast control mimic panels, ie: "Green" means fully open, "Red" means fully closed and no light means "valve in transit". The control valves consist of a "one-way" shuttle valve which on electrical activation of the solenoid allows high pressure air from a compressor into the air supply line for the individual butterfly valve, activating its piston. De-activation of the solenoid allows the air in the supply line and piston to exhaust into the control valve exhaust manifold.

2.7 The solenoid in turn is controlled, through a relay, by the micro command switch pair in the ballast control mimic panel. These are momentary microswitches controlling the self-holding relay. The push button micro command switches on the mimic panel are directly controlled by the ballast control operator, who would select the appropriate valve and pump configuration, in response to the requirements from the drill crew.

ANALYSIS

3.1 The random distribution of light bulb failures and non-failures over the whole mimic panel suggested that water covered the whole panel at the time of the porthole failure.

3.2 For a light bulb to blow due to overvoltage the following conditions were required:

1) the 115 volt supply must have leaked into the 24 volt lamp circuit (the damage to P-19 "green" attests to that having occurred, as also does the physical evidence of the 68 blown light bulbs); and,
2) the bulb would have to be set in the "ON" condition by the limit switch or the light test switch; and,
3) the bulb contacts could not be shorted out by sea water.

Only switches that are shorted out locally by arcing can possibly burnout on their own light bulbs when not in the "ON" condition. This condition only occurred at P-19 "green", which light was not damaged.

3.3 For a light bulb *not* to have blown, the following conditions were required:

1) the bulb would have to be set in the "OFF" condition by the limit switch; and/or
2) the bulb contacts would have to have shorted out by sea water; and/or,
3) no 115 volt leakage into the 24 volt circuit had occurred (the 68 burned out bulbs attest against that having occurred).

3.4 Considering the distribution of bulb failures, the above conditions suggest that the panel had been operated while the sea water was affecting the panel. From the above conditions, it was also clear that evaporation or the draining or cleaning away of the water in the lamp socket could cause its light to burnout.

3.5 Removal of electrical power from the mimic panel could only be effected by pulling circuit breaker NFB1. This would have left only the pump switches functional although disabling the pump switch indicator lights. Removal of the electrical power would cause all open pneumatically operated valves to close. The only reasonable way to operate these valves after power is removed is with the brass actuator rods as described in Report "C".

3.6 It should be noted that the only valves that showed evidence of having been operated by the brass rods were tank valves, as is known from Report "C". Therefore if electrical power was removed from the panel, the manual operation of the tank valves alone appear to be totally non-effectual because other valves should have also been open to effect and control flow.

3.7 Portholes or side scuttles have mostly been designed and standardized with ships in mind and not drilling rigs. In general a ship is rarely anchored stiffly against the waves as is the typical condition for a drilling rig. Therefore, it is considered reasonable to expect that a porthole in a rig would get a much more severe pounding than in a ship. In view of its application it should not have been considered unlikely that this porthole would have failed.

3.8 Damage to the ballast control electrical system removes from the operator his only source of information in relation to the stability control of the rig. There was no back up system in the ballast control room, other than the manual (brass rod) operation of the solenoid control valves. However it is considered that the inconspicuous identification and the awkward-to-reach location of the valves would make manual operation in an emergency very difficult, if not impossible.

3.9 It is considered that most of the ballast control electrical equipment appeared to be an undesirable complexity in the system. The whole pneumatic system could have been easily and conveniently controlled by hand operated spigot type valves located directly in the mimic panels, eliminating 64 relays, 128 switches and 64 solenoid valves. Two or more separate "red" and "green" indicator light mimic panels directly wired to the limit switches on the valve pistons would then provide status information in various locations. The valve panel should also have been duplicated on the bridge for emergencies.

CONCLUSIONS

Answers to the requests of the Commission as listed in 1.2 are as follows:

4.1 All photographs requested will be submitted to the Commission together with this report.

4.2 A full analysis of the two broken portholes is contained in Report "A", attached.

4.3 The results of the porthole glass pressure tests are contained in Report "B" attached.

4.4 Evidence of manual operation of the solenoid control valves is contained in Report "C" attached.

4.5 An analysis of the rubber plugs in the solenoid valve housing is contained in Report "C" attached.

4.6 The valve positions of the valves with manual actuator rods inserted are listed in Report "C" attached.

4.7 An analysis of all switches is contained in Report "D" attached.

4.8 An analysis of all indicator lights is contained in Report "D" attached.

4.9 An analysis of all light bulbs is contained in Report "E" attached.

4.10 An analysis of the switches and indicators' susceptibility to salt-water damage is contained in Report "F" and Report "G" attached.

4.11 The results of the control panel salt-water tests are contained in Report "F" attached.

4.12 The analysis of the ballast control electrical system is covered in Report "G" attached.

REPORT "H"
ENGINEERING REPORT EP 72/84
PUMP SWITCH FAILURE DEMONSTRATION
01 March 1984

INTRODUCTION

1.1 The Royal Commission investigating the *Ocean Ranger* Marine Disaster requested the Aviation Safety Engineering (ASE) Facility, of the Aviation Safety Bureau, Transport Canada to assist in the investigation by conducting certain tests and analyses on the ballast control room portholes, the ballast control (mimic) switch panels and the ballast control solenoid valves.

1.2 The results of these tests and analysis were submitted to the Commission in September 1983 in ASE Reports "A" through "G". However, in order to clarify the proposed scenario that sea water entered the pump switches from below the ballast control panel, after the porthole failure, it was requested that ASE carry out supplementary testing on new pump switches to demonstrate that water can indeed run along the bottom of the control panel, enter the pump switches and eventually cause 115 volts AC to leak into the 18 volt AC switch light bulb circuit and burnout the light bulb filament by an over-voltage as proposed in paragraph 3.2 of ASE Report "E", (EP 332/83).

TESTING AND ANALYSIS

2.1 For recording convenience, the pump switch light failure tests were split into two separate tests:

1) a demonstration that water can flow along the bottom of a slightly inclined (12 degrees) horizontal panel;
2) that sea water, once entered into the switch near its light bulb terminals, can in fact cause the light bulb to burn out.

2.2 The pump switches tested were identical to the switches recovered from the *Ocean Ranger*. They were manufactured by Tokyo Electric Co. under part number 4031E-11R for the red "Stop" switch and 1031E-11G for the green "Run" switch.

2.3 The "Stop" switch is a self-latching push button switch which changes state every time it is pushed. The "Run" switch, Photo 1, is a momentary push button switch and activates a self-holding relay to keep the associated pump running. Both switches have a 115 volt to 18 volt transformer built in, to power the light bulb located in the clear plastic green or red button. Photo 2 shows a disassembled "Run" switch with its major parts identified.

2.4 Photo 3 shows the run switch split at the transformer / push button interface. It shows the bottom of the light socket at "A", the secondary transformer winding and terminals at "B", the primary winding and terminals at "C" and the external 115 volt transformer connection terminals at "D".

2.5 The push button part of the switch is constructed and sealed in such a way that water flowing on top of the panel cannot enter the switch body. However if water could reach the switch body from underneath the panel then it can readily flow into the switch near the light bulb connection terminals as indicated in Photo 1.

2.6 The transformer terminals of the primary windings "C" and the light bulb socket "A" are in very close proximity, as is evident from Photo 3. This close proximity would facilitate the leakage of the "primary" 115 volts into the "secondary" light bulb contacts, if sea water were to enter the transformer area within the switch body.

2.7 To demonstrate that water can flow under a horizontal or near horizontal panel a small test fixture was constructed, as depicted in Photo 4. It consisted of a 10 x 24 inch sheet metal panel supported by a simple plywood frame to accommodate a 12 degree slope. A narrow slot about 0.050 inches wide and 6 inches long was cut in the sheet about 4 inches above the pump switch position. A video camera was placed so as to show the bottom of the plate and that portion of the switch that is mounted below the plate.

2.8 The short videotape accompanying this report clearly shows how the sea water, which was poured on top of the panel above the slot, flows through the slot and adheres to the bottom of the panel while running down the incline, and then flows down the side of the switch and into the opening near the light terminals.

2.9 The slot in the test panel was considered to be an acceptable simulation of the small gaps between the rectangular valve switches and the ballast control panel mounting holes that were noted to exist in the ballast control panel assembly.

2.10 For the second test, which demonstrated that the ingestion of sea water can cause an over-voltage in the light bulb causing it to burn out, the switch light bulb terminals were directly wired with 115 volts AC into the transformer primary. Some sea water was injected into the two cavities near the light bulb terminals, Photo 1, while being videotaped. After a few minutes the light changed brightness, flickered, went out and back on again, then flashed very brightly, indicating an over-voltage and failure by burnout. The accompanying videotape has this event recorded for demonstration.

2.11 It was noted that new bulbs did not burn out under the above described test conditions. However the primary transformer windings burned out every time the 115 volt supply was left on for more than fifteen minutes after the application of sea water. The voltage "surges" observed in the "secondary" light bulb circuit were only up to approximately 25 volts and were of relatively short duration; therefore, only light bulb filaments weakened by age were susceptible to burnout.

2.12 It must be noted that the increase in incandescence of a light bulb filament, when it burns out, is not necessarily the result of an increase in the supply voltage but rather can be due to a release of inductive energy as a result of the filament fracture.

2.13 Of the 24 pump switches recovered with the *Ocean Ranger* ballast control panels, only one (the port side #1 bilge pump stop switch) transformer had a burned out primary winding. All other pump switch transformers were electrically undamaged. This would indicate that either not much water entered the switches or, more likely, that the power was removed from the pump circuits not long after water damage was noted. Twelve of the 24 lights were found burned out in the *Ocean Ranger* pump switches (11 red and 1 green). Only lights that were on at the time that water entered the switch bodies could possibly have burned out.

2.14 During the tests it was also noted that considerable amounts of condensation formed in the push buttons, due to the heat of the light bulb. The videotape shows evidence of this type of condensation. This may explain why 14 of the 24 red and green buttons were missing when the control panels were recovered. The crew could well have removed the buttons in their clean up efforts, after noticing erratic behaviour of the lights and/or condensation in the buttons.

CONCLUSIONS

3.1 It has been demonstrated that sea water could easily have (and most likely did) run along the underside of the ballast control panel and entered the pump switch bodies near the light terminals.

3.2 It has also been demonstrated that the pump switch indicator lights can burn out after the entry of sea water, providing the light bulb filament was substantially damaged by age.

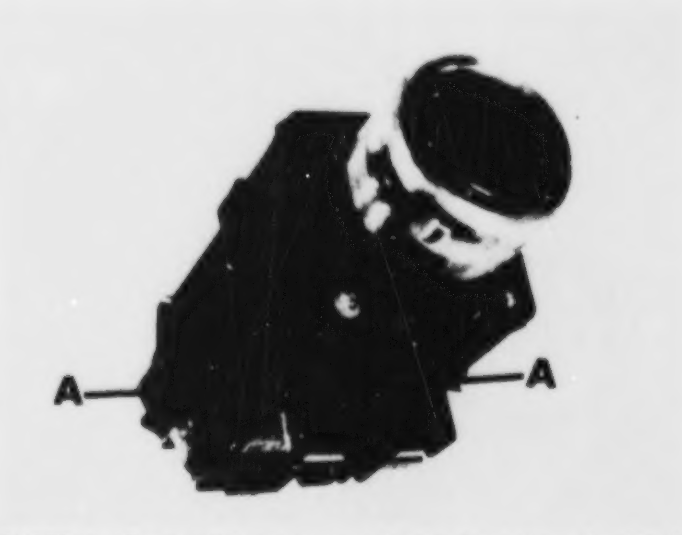


PHOTO 1 Pump switch *green* or *run*, showing the cavity on the side of the body where water can enter at *A*.

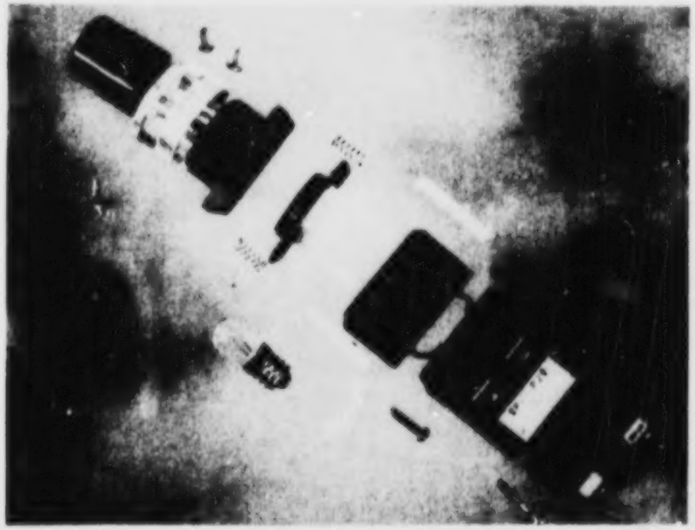


PHOTO 2 The same pump switch disassembled.

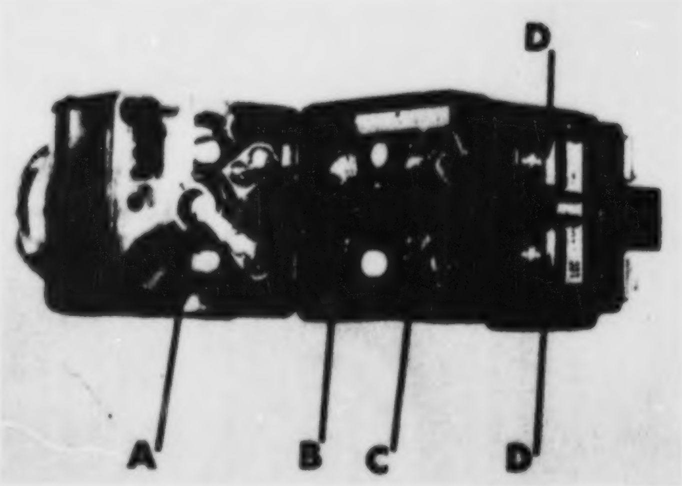


PHOTO 3 The same switch split at the transformer and button light interface. *A* is the bottom of the light bulb socket, *B* secondary winding, *C* is the primary winding and *D* is the external transformer connections.

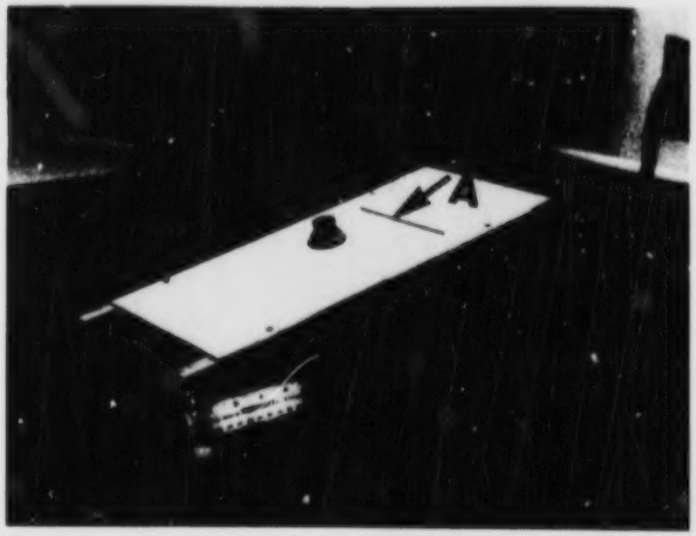


PHOTO 4 The test fixture for water ingestion test, showing the slot at A.

REPORT "I"
ENGINEERING REPORT EP 73/84
MICROSWITCH FAILURE ANALYSIS
01 March, 1984

INTRODUCTION

1.1 The Royal Commission investigating the *Ocean Ranger* Marine Disaster requested the Aviation Safety Engineering (ASE) Facility, of the Aviation Safety Bureau, Transport Canada to assist in the investigation by conducting certain tests and analyses on the ballast control room portholes, the ballast control (mimic) switch panels and the Ballast Control solenoid valves.

1.2 These tests and analyses were completed and the results were submitted to the Royal Commission in September 1983 in ASE Reports "A" through "G". ASE's Report "F", (EP 333/83) titled "Ballast Control Panel Tests", covered testing of a reconstructed ballast control panel for its susceptibility to electrical damage and failure, when doused with sea water. During this test ten control valve "open" (green) switches failed, as is evident from Photo 1 and paragraph 3.4 in ASE Report "F".

1.3 The green light display on the special monitoring panel shown in Photo 1 was the basic evidence that these switches had failed at the time of the test. The manner of failure of these 10 switches, as postulated in paragraph 3.4 of ASE Report "F", was a logical deduction from indirect evidence. At the time of this test it was decided not to open the microswitches to look for sea water, because of the risk of losing the evidence (i.e., the sea water) in the process of opening the switches.

1.4 The valve control switches were removed from the test panel, identified and stored in open plastic bags, in a low humidity environment, for a period of three months, to allow any sea water to evaporate and leave identifiable salt deposits within the microswitch, if sea water had indeed entered the switches.

1.5 For positive and direct proof that sea water can enter the valve control microswitches it was requested by the Commission Counsel that ASE open a selection of microswitches from the test panel described in ASE Report "F", after an appropriate drying period, and determine if there indeed was any evidence to show sea water had entered the microswitches.

EXAMINATION AND ANALYSIS

2.1 The microswitches from the ten valve control "open" (green) push button switches, referenced in paragraph 3.4 of ASE Report "F", were removed and one side of each was gently abraded away to reveal its mechanism, as is shown in Photo 2. A detailed microscopic examination showed small white specks in varying numbers in all of the ten switches. Photo 3 shows typical white specks in one of these switches.

2.2 Scanning electron microscopic analysis revealed the white specks to be largely of a spikey crystalline shape as shown in Photos 4 and 5. Energy dispersive X-ray spectrometric analysis revealed that these specks were various crystalline compounds of sodium and/or chloride, as described in more detail in the ASE Report by the Physical Analysis Specialist, attached.

2.3 The most likely place for sea water to have entered the microswitch was around the red activation button, as shown in Photo 2. However, one of the switches showed that sea water had entered through a space in between the two halves of the switch housing which was apparently not properly sealed with cement, as is evident in Photo 6.

CONCLUSION

3.1 It was determined through energy dispersive X-ray spectrometric analysis that sea water had entered the valve control "open" (green) switches indicated in paragraph 3.4 of ASE Report "F".

Department of Transport
AVIATION SAFETY
ENGINEERING LABORATORY
Internal Request for
Technical Analysis

REQUIREMENTS

Please identify the white deposits found on some microswitch components.

4 February 1984 M. Vermij

FINDINGS

Scanning Electron Microscope (SEM) examination of the "white" deposits on three locations of the microswitch, including two of the gold plated bus bars and one silver contact surface, indicates a wide variation in precipitate morphology – as per attached photomicrographs, see Photos 7 and 8.

Energy dispersive X-ray analysis confirms the presence of a corresponding number of different chemical species, although common to all analyses are high concentrations of sodium, chlorine and other typical constituents of sea water.

Attached spectra #1-5 refer as follows:

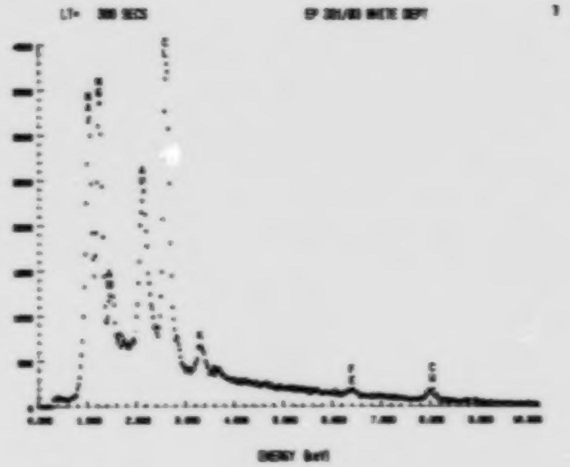
#1, 2 and 3 – random spectral analysis of general background deposits with no well defined crystallographic habits.

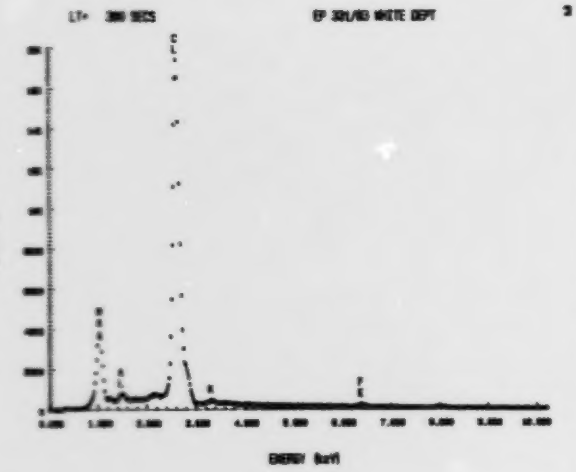
#4 – spectral analysis of typical spikey clusters. Shows sodium salt with minor trace elements suggesting these growths may be sodium compounds with low atomic radicals such as the carbonate, nitrate or oxide which are not detectable by the non-dispersive technique.

#5 – spectral analysis of well developed crystalline phase shown by the longer arrows on Photo 7 and identified as silver chloride.

It can be concluded that all compounds present were derived from reaction with saltwater.

8 February 1984 K.M. Pickwick


LT= 300 SECS
EP 331/83 WHITE DEPT
1
COUNTS
ENERGY (keV)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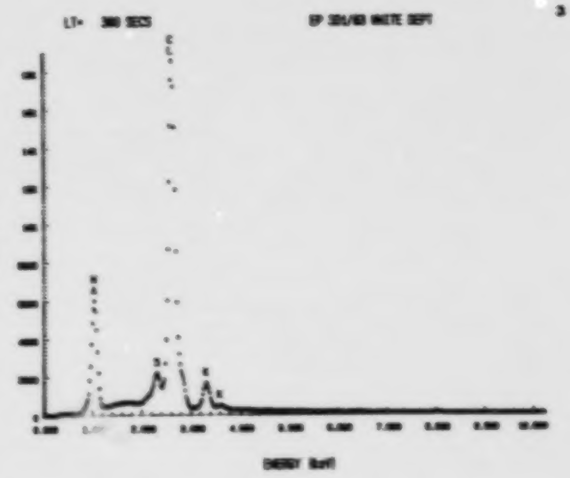
EP 331/83 WHITE DEPT
2
COUNTS
ENERGY (keV)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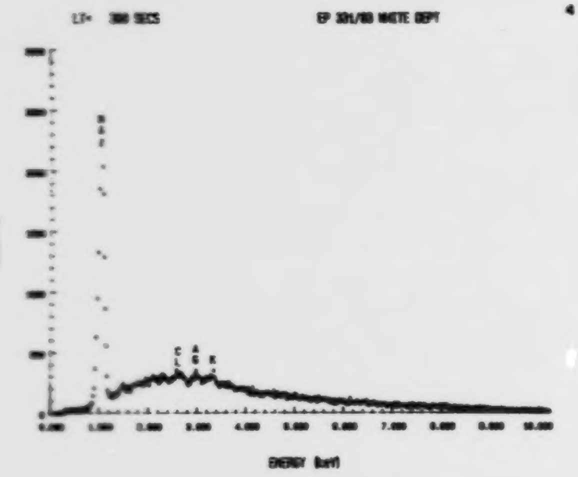
EP 331/83 WHITE DEPT
3
COUNTS
ENERGY (keV)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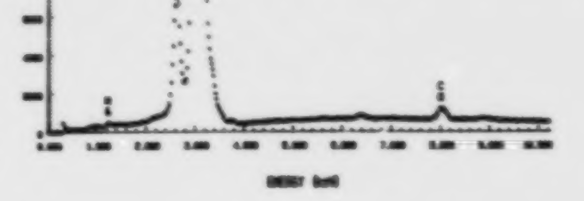
EP 331/83 WHITE DEPT
4
COUNTS
ENERGY (keV)


LT= 300 SECS
EP 331/83 AG CONTACT
5
COUNTS
ENERGY (keV)

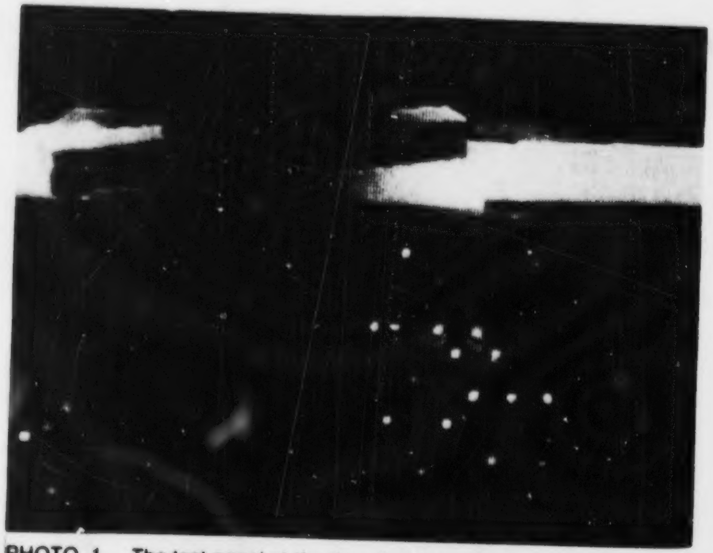


PHOTO 1 The test panel at the time that the monitor panel showed the 10 green lights, indicating switch failures.

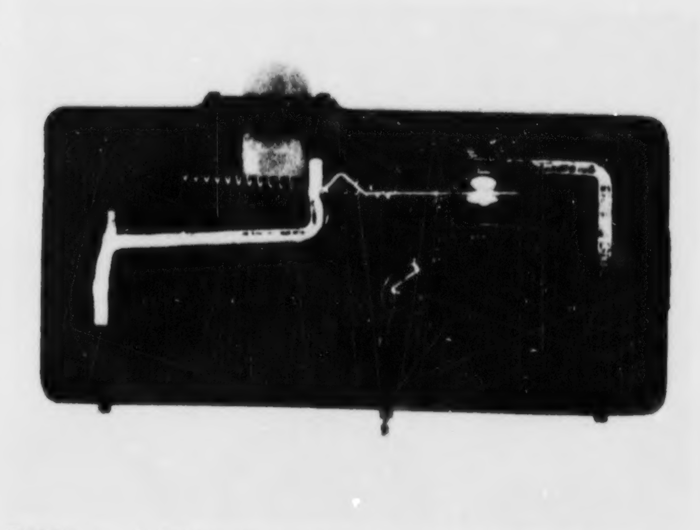


PHOTO 2 A typical microswitch with the side of its housing removed, showing its mechanism.

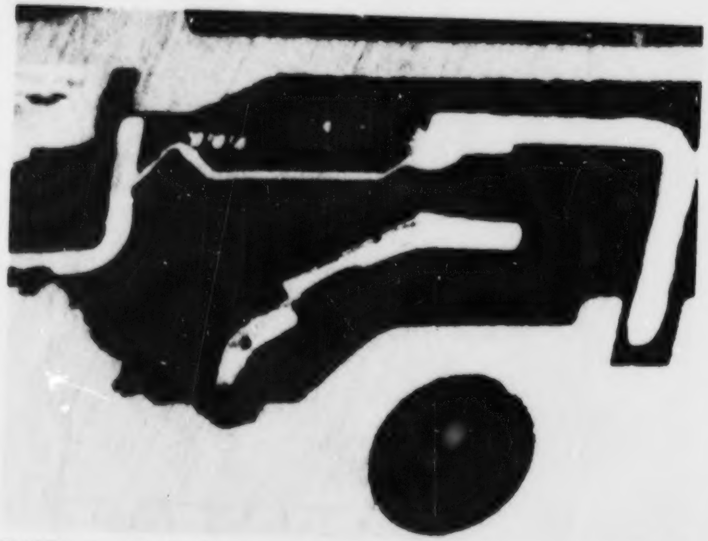


PHOTO 3 Detail of the microswitch mechanism showing the white specks deposited on the gold plated contact bar.

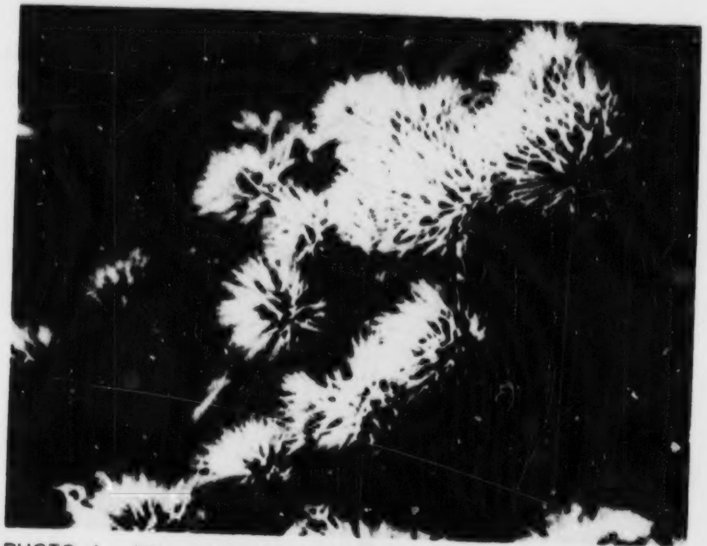


PHOTO 4 Micrograph of the white specks found to be sodium compound crystal clusters.

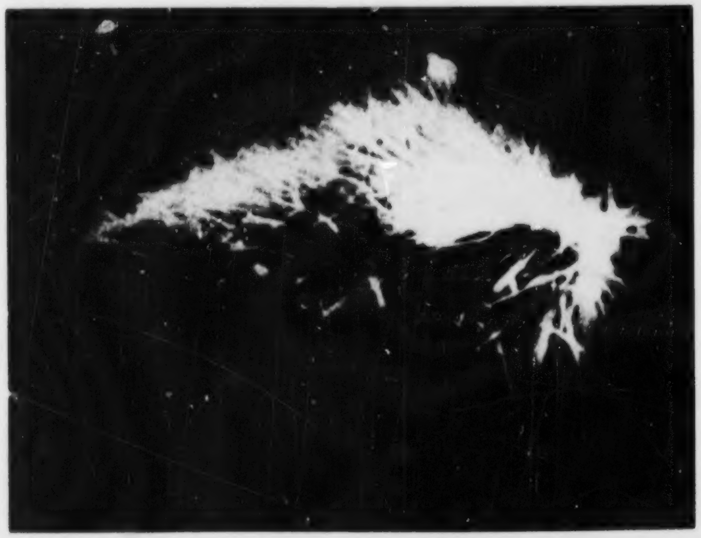


PHOTO 5 Micrograph of a sodium compound crystal cluster surrounded by small sodium chloride crystals.

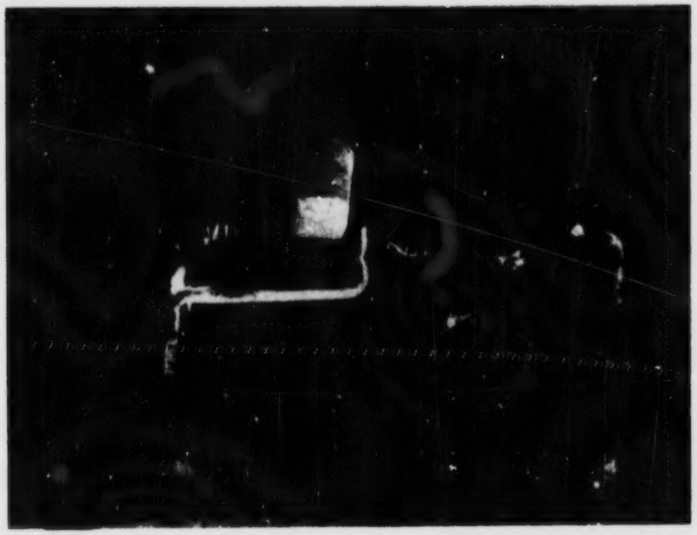


PHOTO 6 Microswitch showing evidence of sea water having entered through a separation in the casing halves.

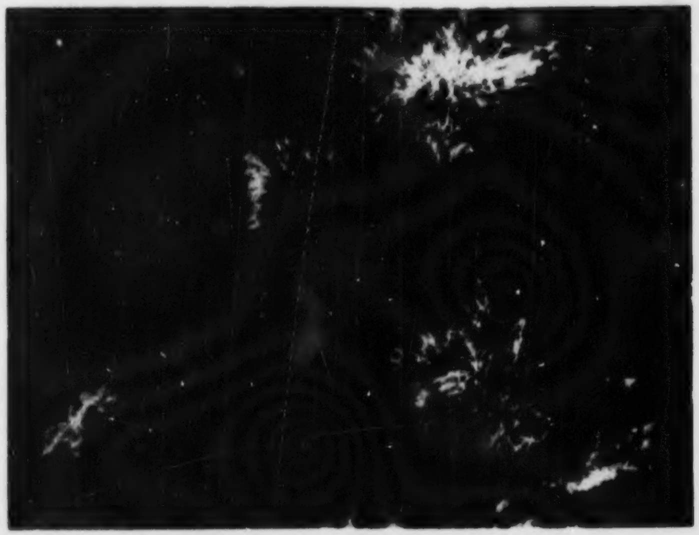


PHOTO 7 Micrograph showing the various crystalline deposits on a switch component.

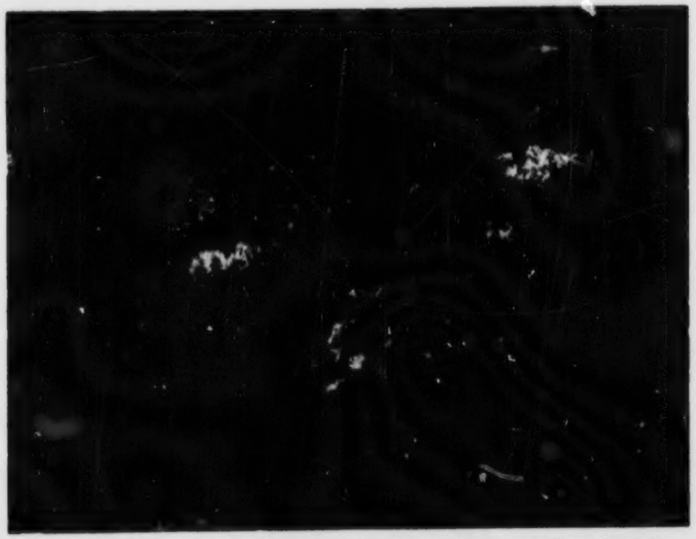


PHOTO 8 Micrograph details of some typical spikey crystalline deposits.

Item F-4

Analysis and Calculations of the *Ocean Ranger* Ballast Pumping System Capability

SUMMARY

It is very likely that the *Ocean Ranger* experienced ballast control problems on the evening of 14th February 1982 which contributed to the total loss of the unit. The following analysis considers some characteristics of the ballast system and its ability to rectify a forward trim.

Since the pump rooms were situated at the after ends of the pontoons, the suction head required when the vessel is trimming forward was increased to such an extent that at 12°, no pump could lift more than about 35% of the number 1 tanks, and no more than about 10% of tanks 2 and 3. At this angle of trim, this is the capacity at which the static suction head is equal to the vapour pressure of the water being pumped. Figure 13 plots the angle of forward trim against the capacity of tanks 1, 2 and 3 showing the point at which the ballast system becomes inoperable.

The constant-speed pump motors cause cavitation at the impellers when pumping with 1 pump from tanks 2 or 3 separately for all angles of forward trim and at zero trim even when the tanks are nearly full. When drawing from tanks 2 and 3 together using 1 pump, cavitation occurs at all forward trims in excess of about 5° when the tanks are full. At zero trim cavitation will occur at all tank levels below approx. 10 ft. or about 38% of their total capacity. It follows that the pumping of the number 1 tanks will also cause cavitation at all levels below approximately 26.5 ft. or about 65% of their total capacity. The exact relationship between cavitation and pumping rate is not known, though in general the pumping rate will decrease in proportion to the degree of cavitation. Cavitation will increase with increasing suction head levels.

In Figure 11 it can be seen that pumping from tanks 2 and 3 on a one-pump/one-tank basis, the allowable flow rate for no cavitation calculated for zero trim ranges from approximately U.S. 1630 GPM when the tank is empty to approximately U.S. 2750 GPM when the tank is full. Analysing the actual design flow rate, i.e., that rate at which the ballast pumps would operate if there was no constraint due to cavitation, it is calculated that the comparable flow rate would range from approximately U.S. 2325 GPM with the tank empty, to U.S. 2590 GPM with the tank full (see Figure 8).

It is normal practice to design a pumping system for zero impeller cavitation, since operating at or beyond the cavitation point produces noise, vibration and rapid erosion of the impeller and the surrounding metal surfaces. In this respect the ballast system on the *Ocean Ranger* was not designed in accordance with good practice, since the pumping capacity was too high to avoid cavitation when pumping from the forward tanks. The reason was, in part, the long run of relatively small-bore piping from the tanks to the pump rooms. This pipe was near the minimum recommended diameter for the design flow rate of the pumps, and caused a considerable dynamic loss in the suction head.

When operating at the design flow rate of a ballast pump (U.S. 2000 GPM), the total suction head in the suction system is calculated to rise to nearly 27 ft. when pumping empty from tanks 2 and 3 on a single tank basis. However, due to the constant speed characteristic of the pumps, the flow rate would be 2300-2600 GPM and the head loss around 39 ft. Pumps such as those fitted in the *Ocean Ranger* would normally be expected to operate on a total maximum suction head (static + dynamic) of no more than about 20 ft. Consequently, the design rate would not be achieved. The total maximum suction head, pumping from two tanks, would be around 24 ft. at achievable flow rates of approximately 2400-2700 GPM.

Part of the problem in pumping from the forward tanks was due to the location of the pump rooms at the after end of each pontoon. When the rig is trimmed, the static suction head is directly related to the horizontal distance between pump and tank bellmouth. Placing the pump room amidships would reduce this suction head considerably. On the *Ocean Ranger* there would be some difficulty in obtaining access to a midships pump room, but this could be achieved from one of the central columns via a watertight tunnel or passage inside the pontoon tanks. A pump room located at both ends of each pontoon would give a positive static head to at least one pump under any condition of trim. Obviously, this would increase the complexity of pipework and control systems, and the operator could well argue that the unit was not designed to operate in a trimmed condition.

Nevertheless, the *Ocean Ranger* has been shown to be easily trimmed through relatively small transfers of ballast. Once in a considerably trimmed-forward condition it is very difficult, with the configuration as built, to see how the pumping system could rectify the problem unless positive air pressure was applied to the tanks. Furthermore, the pump-room-aft configuration placed the centre of gravity of the tank block well forward of the centre of buoyancy. Thus, for normal operating drafts, the after ballast tanks had to be substantially full at all times which limited the trimming aft capability of the rig.

The ballast system of *Ocean Ranger* was arranged so that all pipes from the ballast tanks led aft to a common manifold in the pump room. This manifold was in turn accessed by the pumps and could be used either to fill ballast tanks from the sea or discharge the contents of the tanks overboard. What was not possible, however, was to pump the contents of one ballast tank to another. Instead, it was necessary to pump the first tank overboard and then fill the corresponding or balancing tank with the appropriate amount of water. This arrangement is considered to be unnecessarily limiting and potentially dangerous in the event of malfunction of any valves.

If the forward tanks had been connected by one manifold and the after tanks by another, it would have been possible to pump ballast between forward and after tanks. Figure 14 shows the arrangement as fitted and Figure 15 a suggested alternative, perhaps not optimum, which would be more flexible and permit transfer rather than discharge and replacement. This lack of internal transfer capability must be considered to be a defect in the ballast piping system.

It is reiterated that, due to cavitation, the capacity of the ballast pumps on the *Ocean Ranger* was too large to empty effectively the forward tanks under conditions of forward trim. Cavitation has been shown to occur even under conditions of zero trim.

CONCLUSIONS

1. The ballast system of *Ocean Ranger* was not totally satisfactory in a number of respects. The main deficiencies are considered to be as follows:

i. It was not possible to pump ballast from a forward tank to an after tank or vice versa. A simple modification to the manifold would have made this possible.

ii. The piping from the forward tanks to the after pump rooms was too small in diameter, in relation to the length of run and the pumping capacity. This resulted in cavitation even at zero trim.

iii. The characteristics of the pumping system and location of the pump room limited the capability of the pumps to deballast the forward tanks with the vessel trimmed by the bow. Indeed, with the crucial tanks 1, 2 and 3 in each pontoon, total suction loss would occur at a trim of 6° with the tanks nearly empty and at a trim of 12° with the tanks virtually full. With a trim in the region of 8-10° the pumps were not able to draw from numbers 1, 2 or 3 tanks if they were less than about 45% full.

2. The design of the pumping system did not follow good practice. The total dynamic suction head loss exceeds acceptable limits when pumping individually at design capacity from tank 2 or 3. It was marginally acceptable when pumping from two forward tanks simultaneously, using a single pump.

3. The location of the pump rooms aft placed the centre of gravity of the tank block well forward of the centre of buoyancy. Consequently, at normal operating drafts, the aft ballast tanks had to be substantially full at all times, limiting the trimming aft capability of the rig.

PERFORMANCE CALCULATION

This section describes the method used to determine the ability of the ballast system on the *Ocean Ranger* to deballast the vessel under conditions of both level trim and at varying degrees of trim by the bow.

Since the ballast pumps were situated in the pump rooms at the aft end of the vessel, it follows that the most arduous pumping conditions were imposed by suction from the forward pontoon tanks, i.e., tanks 1, 2, 3 and 4.

Pumping conditions for tanks 2 and 3 are investigated, including some calculations to extend the application of the method to tanks 1 and 4.

PUMP CHARACTERISTICS

Pump specification: Layne & Bowler 'Veriline' close-coupled axial flow centrifugal pump, driven by U.S. 125 HP three-phase electric motor (constant speed 1770 rpm). Design capacity U.S. 2000 GPM at 170 ft system head.

The output of a ballast pump is dependent upon two factors:

a) Total system head: The head-capacity curve is reproduced in Figure 1. As the head increases so the flow decreases and efficiency drops from the design point.

b) Incidence of cavitation: Any axial flow pump, which is impeller driven, will cavitate at some point, dependent upon the rate of flow and the suction lift required. The positive pressure of water around the impeller, for conditions of no cavitation, and expressed as a head of water, is the Net Positive Suction Head (NPSH). This is defined as the difference between the total suction head (including the dynamic head in the suction line) and the head corresponding to the vapour pressure of the liquid pumped. The NPSH curve for the impeller fitted to the *Ocean Ranger* ballast pumps is reproduced in Figure 2.

The effect of pump impeller cavitation on pumping capability is examined numerically in a later section.

BALLAST SYSTEM

Any pumping system is made up of three components: suction line, pump and discharge line. For each pontoon the *Ocean Ranger* could use either one, two or three pumps in parallel, drawing water from one or more tanks and discharging through a common main.

The function of a pump is basically to lift liquid from one level to a higher one. The difference in these two levels is defined as the static head. Losses in pressure due to friction of piping, valves, etc., is defined as the dynamic head. The sum of these two components is the total system head. Since the characteristics of a pump are different for the suction and discharge, the total system head must be divided into total suction head and total discharge head in order to examine its capabilities.

The total system head will vary on the *Ocean Ranger* according to tank level, which affects the static head. The number of tanks pumped simultaneously, and the corresponding flow rate through the suction lines will vary the total friction loss which affects the dynamic head.

This report details two hypothetical pumping conditions:

a) 1 pump acting on 1 tank (1P/1T)

b) 1 pump acting on 2 tanks simultaneously (1P/2T)

It determines the cavitation point of the pump impeller under varying levels of water in tanks 2 and 3; also flow rates from these tanks under conditions of zero cavitation for the two pumping conditions above.

DETERMINATION OF STATIC HEAD

Under any trim condition, the total static head is measured from the level of water in the tank to the point of overboard discharge.

Overboard discharge level
= 32.00m above baseline in the upright condition.

Height of tank bellmouth above baseline
= 0.09m.

Height of pump suction
= 0.915m. This height is taken as the position of the priming propeller, since the priming propeller must develop enough head to reach the second stage suction in order for the pump to function.

Longitudinal position of Nos. 2 and 3 tank bellmouths
= 800mm forward of frame 7.

Longitudinal position of discharge riser
= 3.548m forward of frame 53.

Distance from tank bellmouth to frame 53
= 69.684m.

Distance from bellmouth to discharge riser
= 69.684 − 3.548 = 66.14m.

If angle of trim by the bow = α

Then the vertical distance between the tank bellmouth and the discharge point (maximum static head), is calculated as:

$h_1 = 66.14 \sin\alpha + (32.00 - 0.09) \cos\alpha$ (metres)

Horizontal position of pump centreline
= 5.60 m. aft of frame 53.

Horizontal distance of Nos. 2 and 3 tank bellmouths to pump centreline
= 5.60 + 69.684 = 75.28m

Then the vertical distance between the tank bellmouth and the pump suction (maximum static suction head), is:

$h_2 = 75.28 \sin\alpha + (0.915 - 0.09) \cos\alpha$ (metres)

Then for tanks 2 and 3:

α Degrees	h_1	h_2	h_3 (metres)
0	31.91	0.83	31.08
2	34.20	3.45	30.75
4	36.45	6.07	30.38
6	38.65	8.69	29.96
8	40.80	11.29	29.51
10	42.91	13.88	29.03
12	44.96	16.46	28.50

The values of h_1 and h_2 represent the static heads in the system when the level of water in the tank is level with the bottom of the bellmouth, i.e., the point at which all suction will cease. At intermediate tank levels the head of water in the tank can be deducted from the maximum static head to give the actual static and static suction head. Curves comparing the head of water in the tank against tank percentage capacity for varying trim angles have been prepared for tanks 1, 2, 3 and 4 (see Figures 3-5). For these graphs the head of water has been calculated with the waterplane in the tank trimmed relative to the baseline for all corresponding angles of trim. The static discharge head h_3 will remain constant at selected angle of trim for all tank levels.

DETERMINATION OF DYNAMIC HEAD

Each of the ballast tanks leads to the forward pump room bulkhead by a single ballast line of 200mm diameter standard grade steel pipe. Aft of the pump room bulkhead the ballast lines are fed through a manifold into a common main which varies in diameter from 250mm to 450mm. The discharge main is generally 400mm diameter, connected to the ballast pump with a short length of 250mm diameter pipe.

Length of suction to pump room bulkhead
= 78.25m. (averaged for tanks 2 and 3).

Constrictions to flow:
1 x Bellmouth
3 x 90° bends (assumed R/r = 6)
14 x 45° bends (" " " ")

Length of nominal 200mm suction in pump room
= 1.8m each for tanks 2 and 3.

Constrictions to flow:
1 x Butterfly valve
1 x Expansion (200mm – 450mm)

Length of nominal 450mm suction in pump room

a) Manifold
= 2.60m (averaged for tanks 2 and 3)

Constrictions to flow:
1 x 90° branch (1P/1T)
2 x 90° branch (1P/2T)

b) Branch to strainer
= 2.40m

Constrictions to flow:
2 x 90° branch
1 x Butterfly valve

Length of nominal 250mm suction in pump room (assumed for pump with shortest route)
= 0.95m

Constrictions to flow:
1 x Contraction (450mm – 250mm)
1 x Strainer
1 x Butterfly valve

Length of nominal 250mm discharge
= 3.9m

Constrictions to flow:
1 x Non-return valve
1 x 90° bend
1 x Expansion (250mm – 400mm)

Length of nominal 400mm discharge
= 49.0m

Constrictions to flow:
1 x 90° branch
9 x 90° bends (assumed R/r = 2)
2 x 45° bends (" " " ")
1 x non-return valve
1 x discharge to atmosphere

FRICTION LOSSES

The pressure loss in a piping system due to pipe friction is generally expressed in the form:

$$\text{Pressure loss} = f.\frac{L}{d}.p.\frac{V^2}{2}\ \text{KN/m}^2$$

where:
f = friction coefficient (dimensionless)
L = length of pipe (m)
d = diameter of pipe (mm)
V = Velocity of water through pipe (m/s)
P = density of liquid (kg/m³)

The friction coefficient is dependent upon Reynold's Number, and for this report has been obtained from the *British Standard; Marine Series Specification for Salt-Water Piping in Ships*, which has also been used (unless stated otherwise) for all the foregoing calculations of head loss due to pipe friction and constrictions to flow.

In the foregoing calculations of dynamic friction losses the internal diameters of all piping have been taken from *Ocean Ranger Ballast System Analysis* by Ralph W. Loomis, an ODECO engineer.

Friction factors used throughout apply to new steel pipes. The friction factor corresponding to the design flow of 2000 gpm has been used for all flow rates under investigation.

The pressure loss due to friction can be equated to a head loss by $P = pgh$.

$$\text{Head loss } h = f.\frac{L}{d}.\frac{V^2}{2g}$$

1 GPM = 0.0631 litres/sec.

$$\text{and by } V = \frac{Q}{A}$$

$$V = \frac{0.0631 \times Q}{1000 \times \frac{kd^2}{4}} = 8.034 \times 10^{-5} \times \frac{Q}{d^2}\ \text{m/s}$$

where
Q = flow rate (GPM)
d = internal pipe diameter (m)
$h = 3.290 \times 10^{-10} \times \frac{L}{d^5} \times Q^2 \times f$
L = pipe length (m)

All elements of friction loss were calculated on a microcomputer using the above formulation. Input for each element was length, diameter and friction factor. Results are shown in Tables 1-14 for both 1P/1T and 1P/2T combinations.

CONSTRICTIONS TO FLOW

The pressure loss in a piping system due to constrictions is expressed in the form:

$$P = K \times \frac{V^2}{2g} \times \frac{p}{1000}\ \text{KN/m}^2$$

where
K = dimensionless coefficient
V = fluid velocity (m/s)
p = density of fluid (kg/m³)

This can be equated to a head loss, where

$$\text{Head loss } h = K.\frac{V^2}{2g}$$

and since, as shown before,

$$V = 8.034 \times 10^{-5} \times \frac{Q}{d^2}$$

$$\text{then } h = K \times 3.290 \times 10^{-10} \times \frac{Q^2}{d^4}$$

Again each element of constriction loss was calculated by a microcomputer. Input for each element was the constriction coefficient K as set out below, and results are shown in Tables 1-14.

Loss in suction line forward of pump room:

1 x Bellmouth	K = 0.10*
3 x 90° bends	K = 3 x 0.12
14 x 45° bends	K = 14 x 0.07
TOTAL	K = 1.44

*Source: Kempes Engineers Year Book 1977.

Loss in nominal 200mm suction in pump room:

1 x Butterfly valve	K = 0.42
1 expansion 200-450mm	K = 0.65
TOTAL	K = 1.07

Loss in nominal 450mm suction:

a) Manifold 1 x 90° branch	K = 0.90
TOTAL	K = 0.90
b) Branch to strainer	
2 x 90° branches	K = 2 x 0.90
1 x Butterfly valve	K = 0.42
TOTAL	K = 2.22

Loss in nominal 250mm suction:

1 Contraction 400-250mm	K = 0.38*
1 x Strainer	K = 1.31
1 x Butterfly valve	K = 0.42
TOTAL	K = 2.11

*Assumed 1 contraction + 1 expansion + 50% for strainer basket, etc.

Loss in nominal 250mm discharge:

1 x Non-return valve	K = 1.60
1 x 90° bend	K = 0.22
1 expansion 250-450mm	K = 0.38
TOTAL	K = 2.20

Loss in nominal 400mm discharge:

1 x 90° branch	K = 0.90
9 x 90° bends	K = 9 x 0.30
2 x 45° bends	K = 2 x 0.16
1 x Non-return valve	K = 1.60
Discharge to atmosphere	K = 1.00
TOTAL	K = 6.52

TOTAL LOSSES

The total head loss in the system is the summation of friction and constriction loss and is termed the dynamic head of the system. To allow for computation of 1P/2T losses, both the length of pipe and constriction coefficients were doubled in those parts of the system not common to both 1P/1T and 1P/2T combinations. Similarly, in these elements the velocity was halved relative to the flow rate through the pump and common suction/discharge.

The total dynamic head of the system is added to the total static head to give the total system head. Similarly, the dynamic and static heads on the suction side are summed to give the total suction head. The total system head and the total suction head are the two factors affecting the performance of the ballast pump.

The system head is maximum when the water in the tank is at the bellmouth level. From this maximum head may be deducted the levels of liquid in the tanks (see Figures 3-5) at varying capacities and trims, and the resultant net system head compared to the head-capacity curve of the ballast pump to give the design flow rates at various tank levels. Similarly the suction head can be analysed for varying tank levels to determine the cavitation limits on pumping capability.

PUMP CAVITATION

Ultimately, the suction is limited to the point at which the pressure drop is such as to cause the water to vaporize. At a water temperature of 5°C this vapor pressure is approximately 0.9 KN/m². Under stable conditions the pressure at the water surface is equal to atmospheric pressure. At the *Ocean Ranger* site on the night of 14th/15th February 1982 the atmospheric pressure was at its lowest point approximately 975 mb., which is equal to 97.5 KN/m² (1000 mb = 100 KN/m²)

Thus, the maximum pressure loss in suction is equal to 97.5 – 0.9 = 96.6 KN/m²

and by the form $h = \frac{P}{\rho g}$

the equivalent suction head

$$\text{for S.W.} = \frac{96.6 \times 1000}{1025 \times 9.81}$$

$$= 9.61\text{m } (31.53 \text{ ft})$$

As mentioned earlier, any axial flow impeller-driven pump is limited by cavitation to a suction head less than the static vapor pressure of the liquid being pumped. This reduction in head is termed the NPSH (net positive suction head) and bears a relationship to "flow times speed squared" in the form:

$$\frac{\text{litres/sec} \times (\text{rev/min})^2}{\text{NPSH}^{1.5}} = \text{constant}$$

This can also be expressed as:

$$\frac{\text{GPM X rpm}^2}{\text{NPSH}^{1.5}} = \text{constant}$$

Reference to the Layne and Bowler Propeller 10P NPSH curve (reproduced in Figure 2) shows that at 4000 GPM NPSH = approximately 28 ft and at 3000 GPM NPSH = approximately 19 ft.

Using 3000 GPM as the starting point

$$\frac{3000 \times 1770^2}{19^{1.5}} = 1.135 \times 10^8$$

On this basis:

$$\frac{4000 \times 1770^2}{\text{NPSH}^{1.5}} = 1.135 \times 10^8$$

NPSH AT 4000 GPM = 23 ft

This discrepancy in the calculated and actual NPSH figures is thought to be due to the discharge conditions influencing cavitation at high flow rates and the consequent low system heads.

Since further information on NPSH is not available, it is proposed to use NPSH = 19 ft at 3000 GPM as a basis for computing NPSH at lower flow rates using the above relationship and hence computing available suction lift.

GPM	NPSH (m)	Available Suction Lift (m)
1000	2.78	6.83
1250	3.23	6.38
1500	3.65	5.96
1750	4.04	5.57
2000	4.42	5.19
2250	4.78	4.83
2500	5.13	4.48
2750	5.46	4.15
3000	5.79	3.82

Since the flow rate is proportional to the total system head, the flow from the tanks will conform to that relationship up to the point where the required suction lift becomes greater than the available suction lift, i.e., until cavitation occurs.

ANALYSIS OF PUMP CAPABILITY

Tables 1-14 set out the total system and total suction heads for flow rates from 0-3000 GPM at varying bow trims of 0°-12° and at varying tank levels. Tables 1-7 are for 1P/1T pumping and Tables 8-14 for 1P/2T.

The total system head when pumping tanks 2 and 3 was compared graphically with the Layne and Bowler Head Capacity Curve for 1P/1T and 1P/2T combinations at varying tank levels and at forward trim angles. Figures 6 and 7 show these curves for zero trim; similar curves have been prepared for 2° to 12° bow trim. Thus the intersection points give curves of design flow rate vs percentage of total tank capacity for 1P/1T and 1P/2T combinations at all forward trims, reproduced in Figures 8 and 9. As previously stated, these curves are valid only at zero cavitation, i.e., so long as the required suction lift is less than the available suction lift at the point of cavitation of the pump impeller.

In order to determine the cavitation point of the pump impeller, it is necessary to plot the curve of available suction lift for zero cavitation against the curves of required suction lift at varying tank levels. For tanks 2 and 3 at 100% capacity this plot is shown in Figure 10 for 1P/1T and 1P/2T combinations at zero trim. This graph shows that for the 1P/1T combination cavitation will occur at any pump flow rate in excess of 2750 GPM, while the 1P/2T combination will produce pump cavitation under these conditions only at a pump flow rate in excess of the range considered.

Referring back to Figure 8, it can be seen that at zero trim, the 'no cavitation' flow rates through the pump on a 1P/1T combination range through 2325 GPM with the tank empty to 2590 GPM with the tank full. Thus, since this design flow rate is less at full capacity than the flow rate which will cause cavitation, it can be concluded that the pump will not cavitate under these pumping conditions when the tank is full and the rig at zero trim. This also applies to a 1P/2T combination at zero trim, since design flow rates range through 2430 GPM with the tank empty to 2700 GPM with the tank full. In order to determine at which combination of tank capacity and forward trim cavitation is likely to occur, it is necessary to repeat the exercise illustrated in Figure 10 for other tank levels and trims. These calculations are reproduced graphically for all trims in Figures 11 and 12 for both 1P/1T and 1P/2T combinations.

Figures 11a and 12a cross plot the design flow rate curve against the allowable flow curve for tanks 2 and 3 using 1P/1T and 1P/2T combinations at zero trim, zero cavitation. Similar cross plots were prepared for other bow trim angles. Provided that the design flow rate does not exceed the allowable flow rate, cavitation will not occur until the level of water in the tank drops to the intersection of the allowable and design curves. Percentage of tank capacity can be equated to tank level by reference to Figure 4.

Cross plotting in the manner outlined above between Figures 8 and 11, and between Figures 9 and 12, then yields the following results:

A) 1 PUMP/1 TANK

At 0° trim, cavitation will commence when tanks 2 and 3 are at approximately 93% capacity, corresponding to a tank level of approximately 8.1 metres (26.6 ft.).

At and in excess of 2° bow trim cavitation will be present at all tank levels.

B) 1 PUMP/1 TANK

At 0° trim, cavitation will commence when tanks 2 and 3 are at approximately 38% capacity, corresponding to a tank level of approximately 3.1 metres (10.2 ft.)

At 2° bow trim, cavitation commences at approximately 77% capacity, corresponding to a tank level of approximately 5.8 metres (19.0 ft.).

At 4° bow trim, cavitation commences at approx. 94% capacity, corresponding to a tank level of approximately 8.5 metres (27.9 ft.).

At and in excess of 6° bow trim, cavitation will be present at all tank levels.

As can be seen, in order to avoid pump cavitation at all tank levels and zero forward trim, the pump should operate at no more than approximately 1630 GPM with the tank empty on a 1P/1T configuration, and 2030 GPM with the tank empty on a 1P/2T configuration. Owing to the constant-speed nature of the ballast pump motor it is not possible for the pump to achieve these lower pumping rates. The only way of achieving lower pumping rates is to throttle the discharge, producing an artificially large discharge head while leaving the suction head unaltered. Since the pumping rate is proportional to the total system head, this would create the desired effect on pumping rates. No information was available at the time of writing to suggest that any means of throttling the discharge was fitted to the *Ocean Ranger*. On this basis this report concludes that the *Ocean Ranger*'s ballast pumps were of too great a capacity given their location and the piping characteristics. This is true when pumping one tank with one pump, or even two tanks simultaneously. It is normal practice for a ballast pump to be sized according to the required suction lift while retaining some margin above the NPSH for the pump, since operating at or beyond the cavitation point produces noise, vibration and rapid erosion of the surrounding metal surfaces. The net operating suction lift is usually designed to be in the region of 5m to 7m with a safety margin on NPSH of 2m and upwards. Any suction pump will be ultimately limited to the point at which the static (zero flow) suction head is equal to the vapor pressure of the liquid being pumped. For water this has been shown to be a suction head of 9.61m. Figure 13 shows a plot of angle of forward trim against percentage capacity of nos. 1, 2 and 3 tanks beyond which no suction is possible. It should be borne in mind that these curves show ultimate loss of suction at zero flow, and no inference should be drawn that the curves are in any way representative of the actual capability of the *Ocean Ranger* Ballast System, which, even new, would be less than the theoretical figures. The theoretical figures would be even less representative of the system after 6 years in service.

[Editors note: Editorial changes have been made to this report, with the author's approval, to assist in publication.]

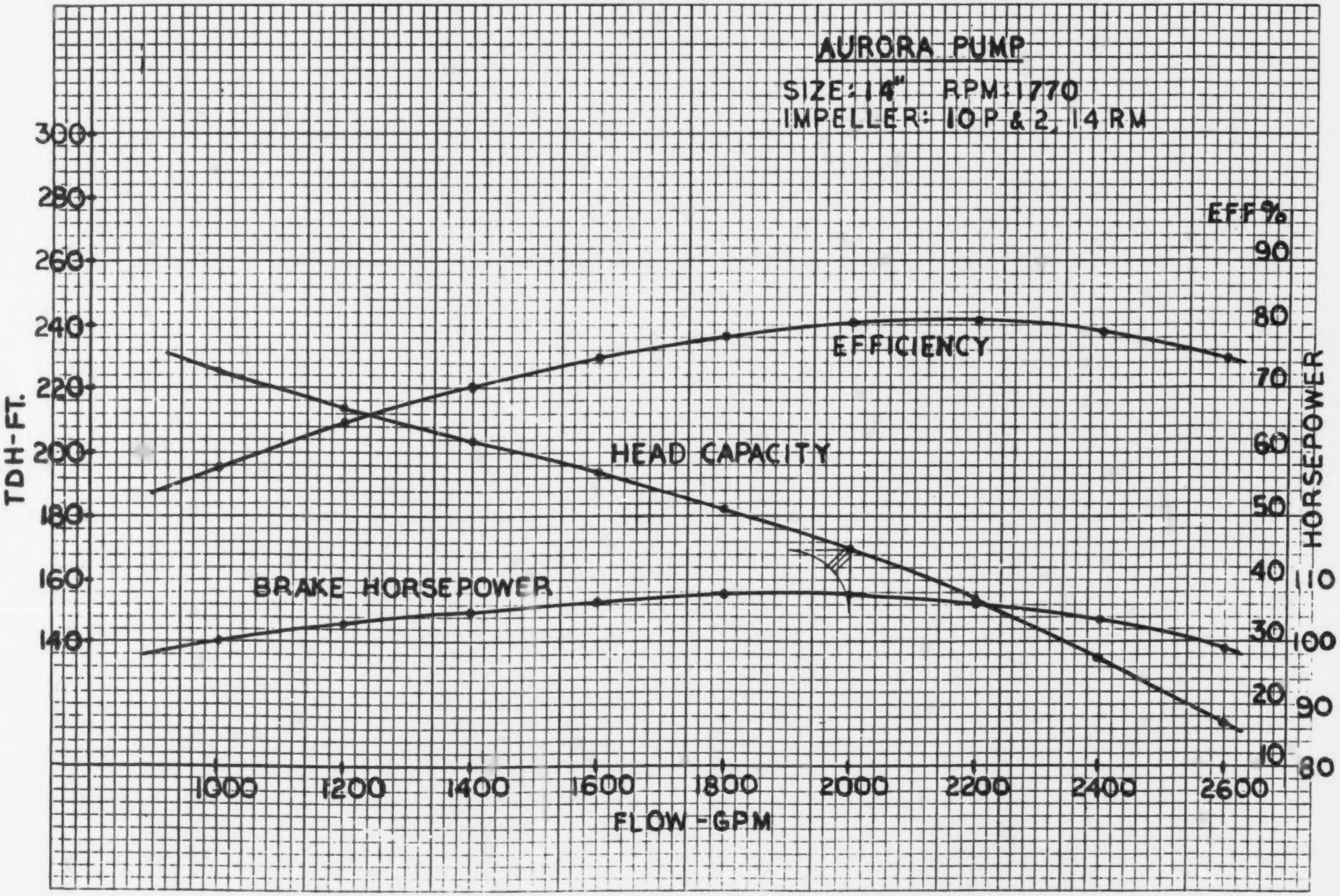
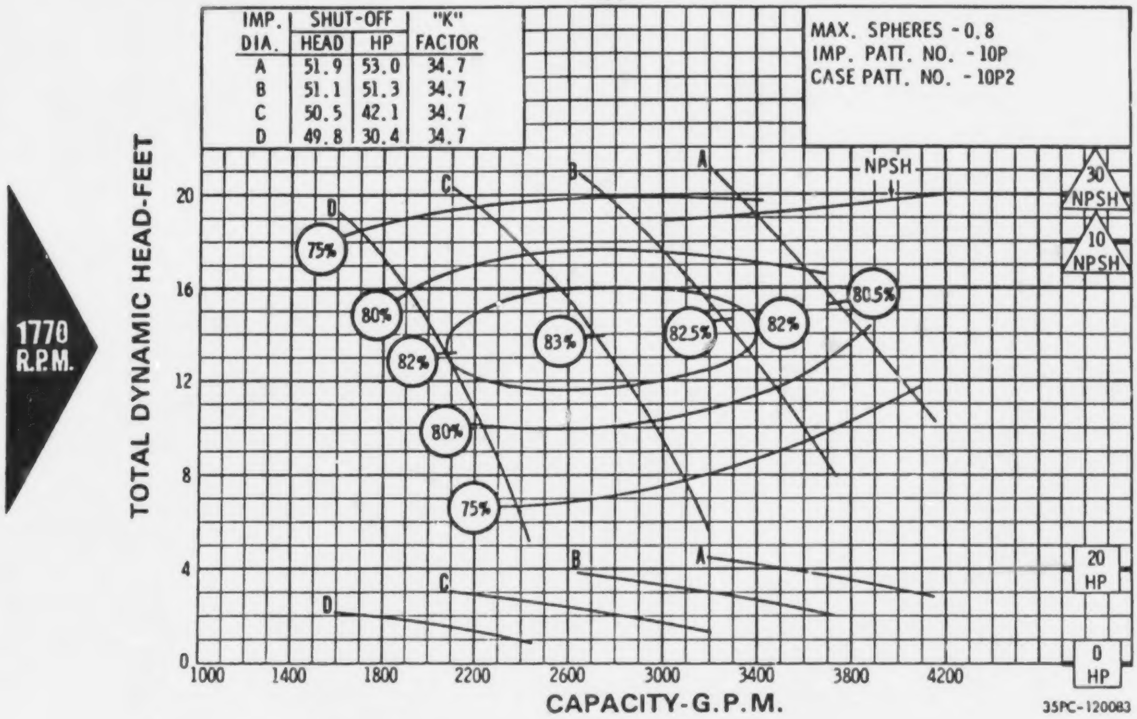

AURORA PUMP
SIZE: 14" RPM: 1770
IMPELLER: 10P & 2, 14 RM
TDH-FT.
300
280
260
240
220
200
180
160
140
EFF%
90
80
70
60
50
40
30
20
10
HORSEPOWER
110
100
90
80
EFFICIENCY
HEAD CAPACITY
BRAKE HORSEPOWER
1000
1200
1400
1600
1800
2000
2200
2400
2600
FLOW - GPM

FIGURE 1

DATED **NOVEMBER 1972**

PROPELLER
10P



IMP. DIA.	SHUT-OFF HEAD	SHUT-OFF HP	"K" FACTOR
A	51.9	53.0	34.7
B	51.1	51.3	34.7
C	50.5	42.1	34.7
D	49.8	30.4	34.7

MAX. SPHERES - 0.8
IMP. PATT. NO. - 10P
CASE PATT. NO. - 10P2

FIGURE 2

% TOTAL TANK CAPACITY v. HEAD OF WATER ABOVE BELLMOUTH
PT-1 / ST-1
NOTE: HEAD OF WATER IS MEASURED NORMAL TO WATERPLANE FOR ALL α

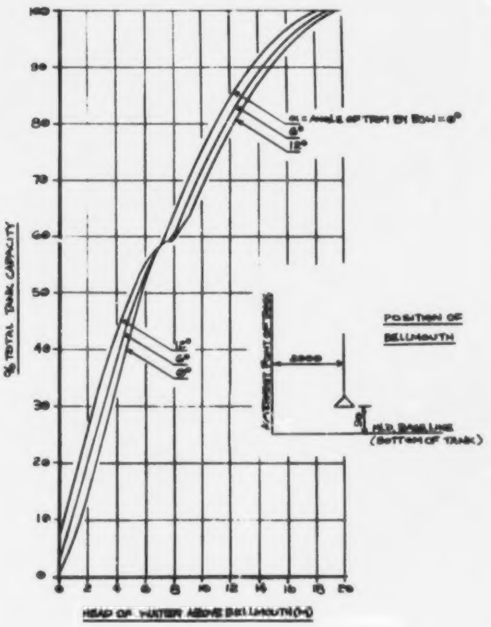


FIG. 3

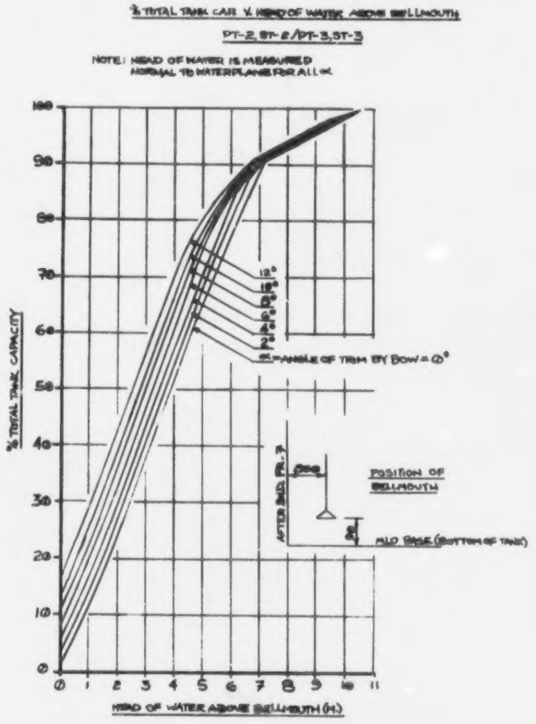


FIG.4

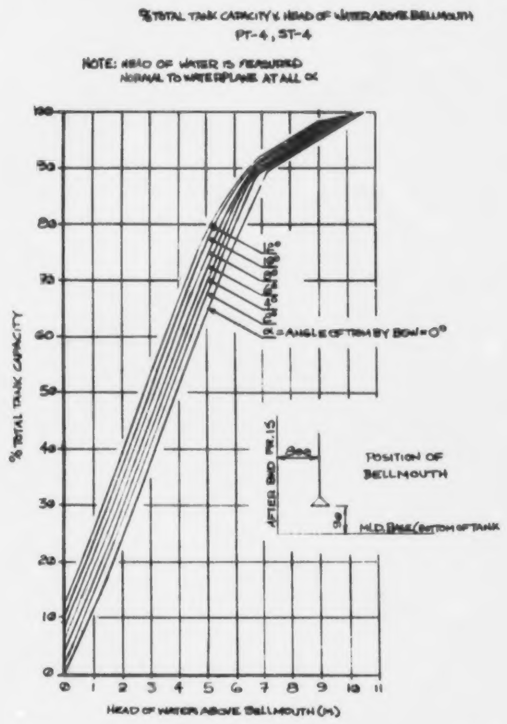


FIG.5

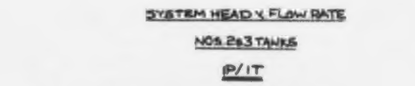


FIG.6

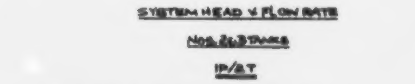


FIG.7

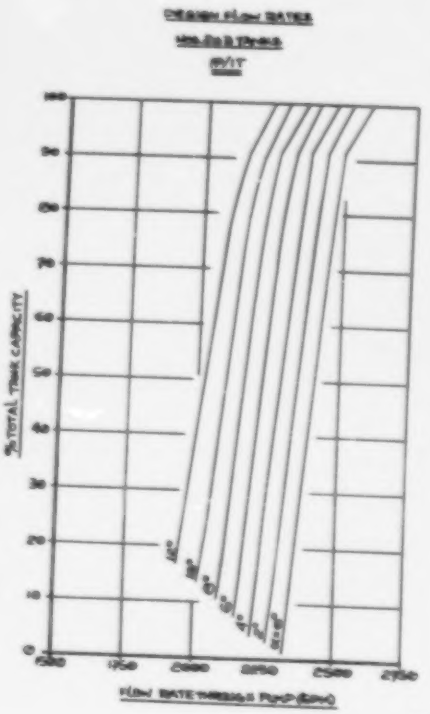

DESIGN FLOW RATES
NOS. 2 & 3 TANKS
1P/1T

FIG. 8

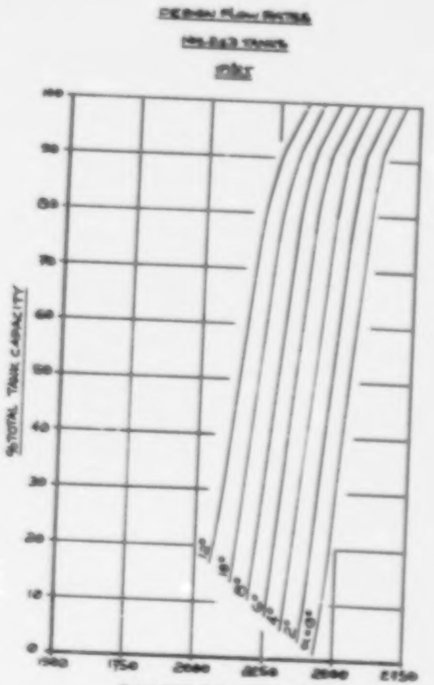

DESIGN FLOW RATES
NOS. 2 & 3 TANKS
1P/2T

FIG. 9

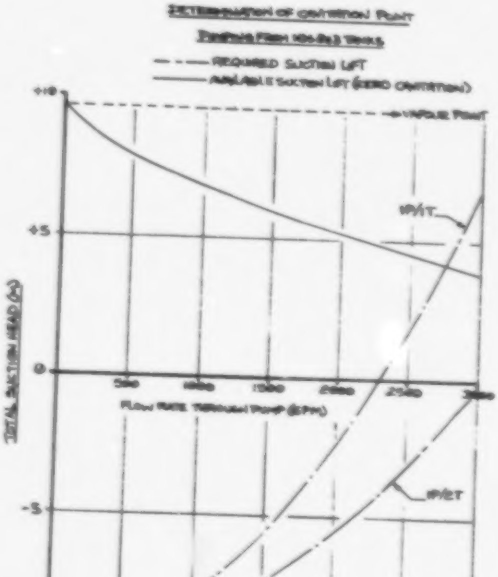

DETERMINATION OF CAVITATION POINT
PUMPING FROM NOS. 2 & 3 TANKS

FIG. 10

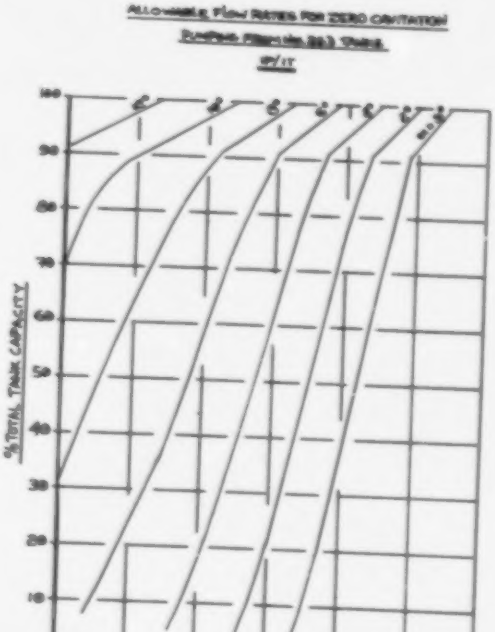

ALLOWABLE FLOW RATES FOR ZERO CAVITATION
PUMPING FROM NOS. 2 & 3 TANKS
1P/1T

FIG. 11

COMPARISON OF DESIGN
AND CAVITATION-FREE FLOW RATES
IP/1T θ=8°
PUMPING FROM NOS. 2 & 3 TANKS

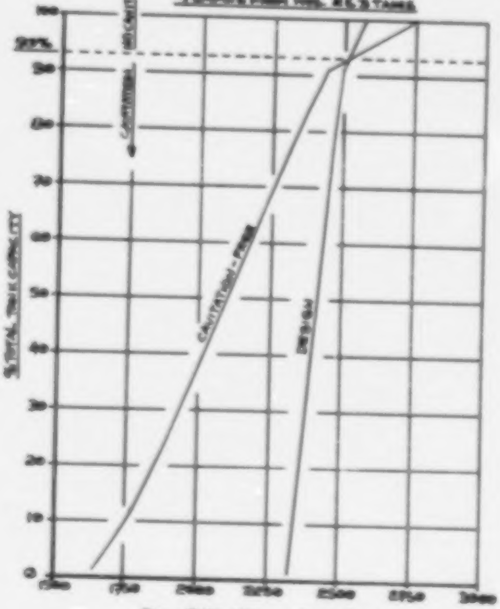


FIG. 11A

ALLOWABLE FLOW RATES FOR ZERO CAVITATION
PUMPING FROM NOS. 2 & 3 TANKS
IP/8T

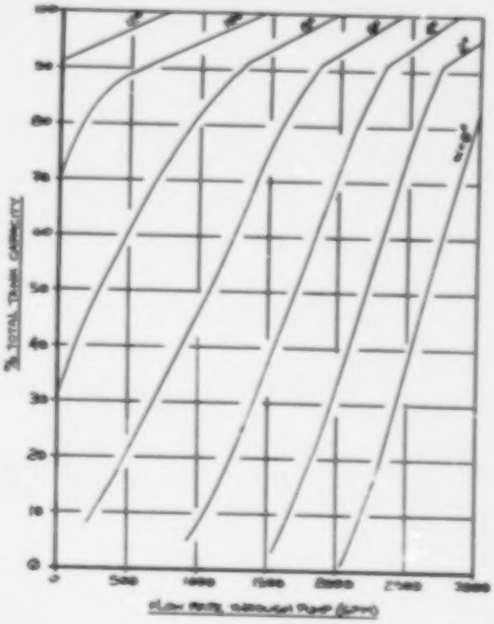


FIG. 12

COMPARISON OF DESIGN
AND CAVITATION-FREE FLOW RATES
IP/8T θ=8°
PUMPING FROM NOS. 2 & 3 TANKS

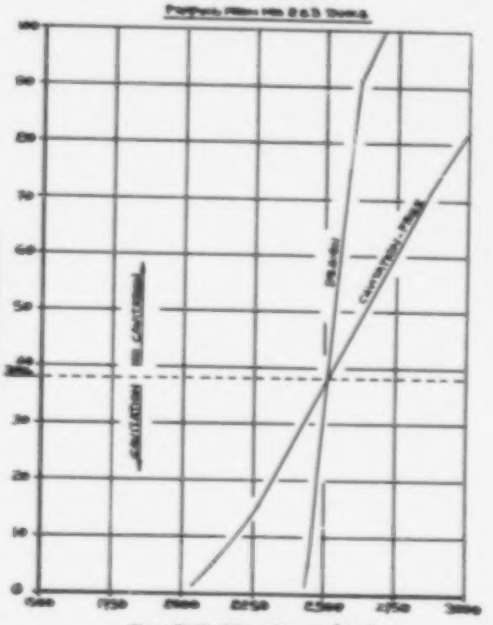


FIG. 12A

CAPACITY OF TANKS BELOW WHICH
BALLAST SUCTION IS INOPERABLE
(BASED ON MAX SUCTION HEAD = 5.6 m.)

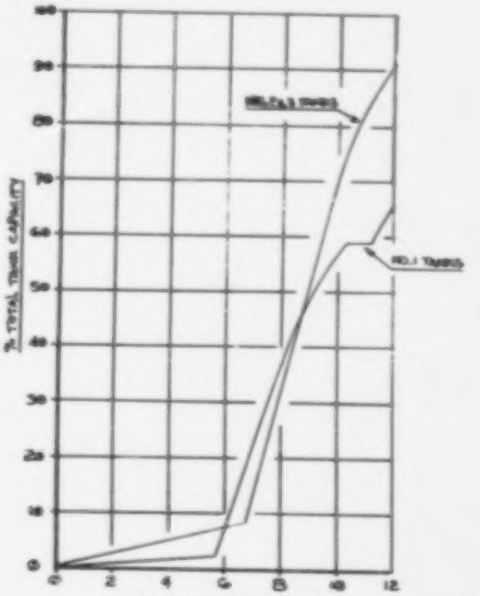


FIG. 13

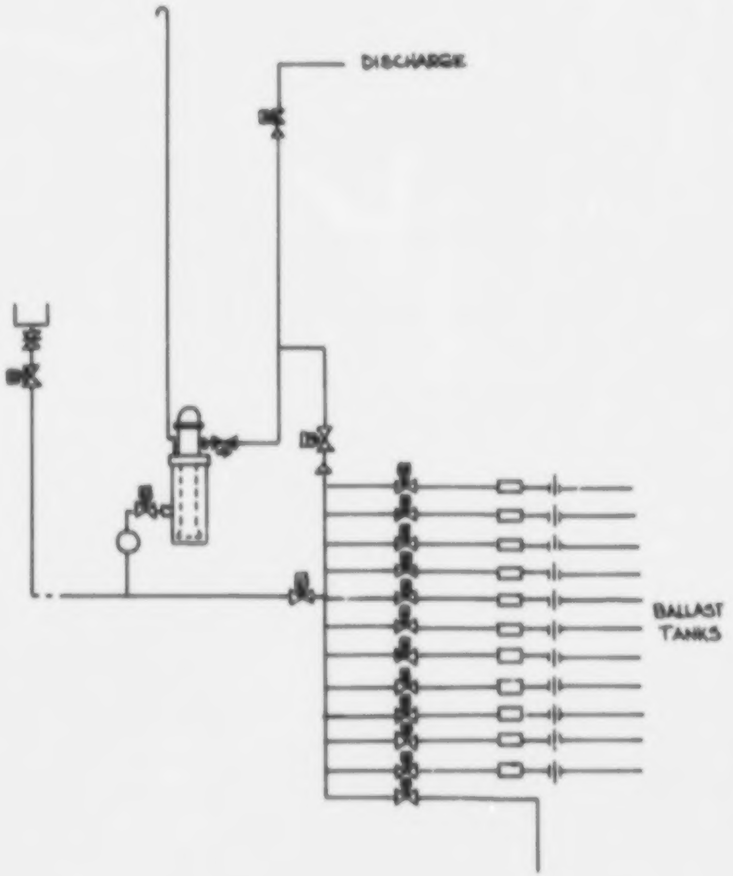

DISCHARGE
BALLAST TANKS

FIGURE 14

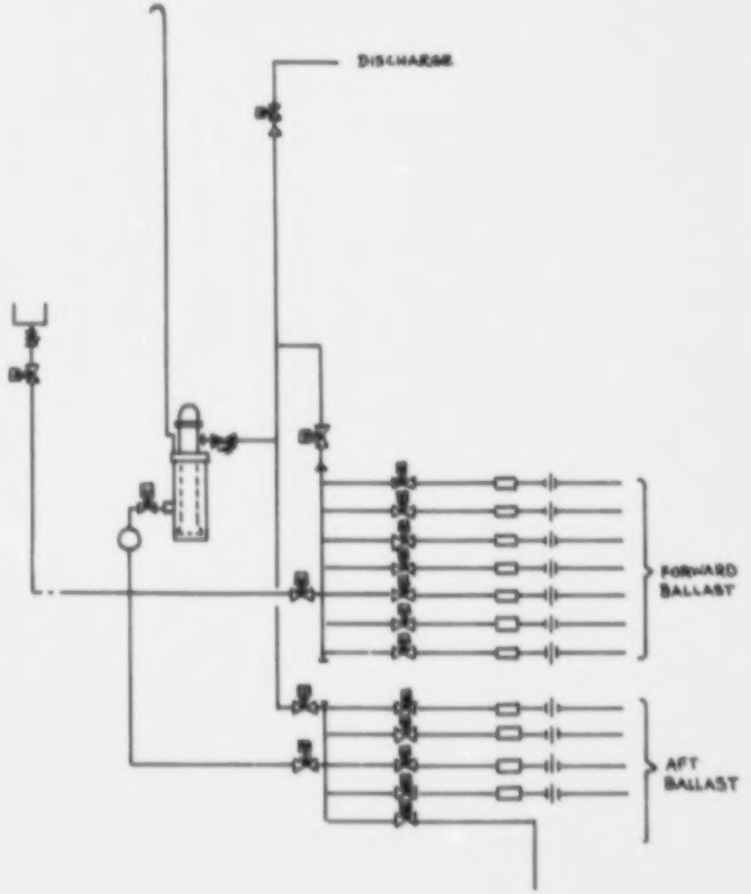

DISCHARGE
FORWARD BALLAST
AFT BALLAST

FIGURE 15

TABLE 1

analysis of ocean ranger ballast system

calculation of total system and suction system heads   flow rate = 2013 gpm

description of pipe system	suction in pontoon	suction in pumproom	suction in manifold	suction in pumproom	suction in pumproom	discharge	discharge
length (metres)	70.25	1.00	2.60	2.40	0.95	3.90	[illegible]
diameter (m)	.2047	.2047	.4318	.4318	.254	.254	.305
velocity (m/s)	3.83	3.83	0.86	0.86	2.49	2.49	1.71
reynolds x10^-6	0.50	0.50	0.24	0.24	0.40	0.40	0.27
friction factor	.016	.016	.016	.016	.016	.016	.016
h(f) friction	6.12	0.14	0.12	0.09	0.06	0.25	2.06
h(c)constriction	1.44	1.07	0.96	2.22	2.11	2.20	6.52
h(t) total	7.56	1.21	1.08	2.31	2.17	2.45	8.58
dynamic head (metres)	5.65	0.91	0.84	0.09	0.60	0.77	0.53

flow rate q (gpm)	total dynamic head m	total static head m	total system head m	suction dynamic head m	suction static head m	suction system head m
0	0.00	31.91	31.91	0.00	0.83	0.83
250	0.14	31.91	32.05	0.12	0.83	0.94
500	0.54	31.91	32.45	0.46	0.83	1.29
750	1.22	31.91	33.13	1.04	0.83	1.86
1000	2.17	31.91	34.08	1.84	0.83	2.67
1250	3.39	31.91	35.30	2.88	0.83	3.70
1500	4.88	31.91	36.79	4.14	0.83	4.97
1750	6.64	31.91	38.55	5.64	0.83	6.46
2000	8.67	31.91	40.58	7.36	0.83	8.19
2250	10.97	31.91	42.88	9.32	0.83	10.14
2500	13.54	31.91	45.45	11.50	0.83	12.33
2750	16.39	31.91	48.30	13.92	0.83	14.75
3000	19.50	31.91	51.41	16.57	0.83	17.39

static total head = 31.91

static suction head = .825

pumping tank 2 or 3

1 Pump / 1 Tank

Trim in degs. = 2

flow rate q (gpm)	total system head: bellmouth	25%	50%	75%	90%	100%	suction system head: bellmouth	25%	50%	75%	90%	100%
0	31.91	29.81	28.06	26.13	24.79	21.33	0.83	-1.28	-3.03	-4.96	-6.30	-9.76
250	32.05	29.95	28.20	26.27	24.93	21.47	0.94	-1.16	-2.91	-4.84	-6.18	-9.64
500	32.45	30.35	28.60	26.67	25.33	21.87	1.29	-0.81	-2.56	-4.49	-5.83	-9.29
750	33.13	31.03	29.28	27.35	26.01	22.55	1.86	-0.24	-1.99	-3.92	-5.26	-8.72
1000	34.08	31.98	30.23	28.30	26.96	23.50	2.67	0.57	-1.18	-3.11	-4.45	-7.91
1250	35.30	33.20	31.45	29.52	28.18	24.72	3.70	1.60	-0.15	-2.08	-3.42	-6.88
1500	36.79	34.69	32.94	31.01	29.67	26.21	4.97	2.87	1.12	-0.81	-2.15	-5.61
1750	38.55	36.45	34.70	32.77	31.43	27.97	6.46	4.36	2.61	0.68	-0.66	-4.12
2000	40.58	38.48	36.73	34.80	33.46	30.00	8.19	6.09	4.34	2.41	1.07	-2.39
2250	42.88	40.78	39.03	37.10	35.76	32.30	10.14	8.04	6.29	4.36	3.02	-0.44
2500	45.45	43.35	41.60	39.67	38.33	34.87	12.33	10.23	8.48	6.55	5.21	1.75
2750	48.30	46.20	44.45	42.52	41.18	37.72	14.75	12.65	10.90	8.97	7.63	4.17
3000	51.41	49.31	47.56	45.63	44.29	40.83	17.39	15.29	13.54	11.61	10.27	6.81

TABLE 2

analysis of ocean ranger ballast system

calculation of total system and suction system heads   flow rate = 2000 gpm

description of pipe system	suction in pontoon	suction in pumproom	suction in manifold	suction in pumproom	suction in pumproom	discharge	discharge
length (metres)	70.25	1.00	2.60	2.40	0.95	3.90	[illegible]
diameter (m)	.2047	.2047	.4318	.4318	.254	.254	.305
velocity (m/s)	3.83	3.83	0.86	0.86	2.49	2.49	1.71
reynolds x10^-6	0.50	0.50	0.24	0.24	0.40	0.40	0.27
friction factor	.016	.016	.016	.016	.016	.016	.016
h(f) friction	6.12	0.14	0.18	0.09	0.06	0.25	2.06
h(c)constriction	1.44	1.07	0.90	2.22	2.11	2.20	6.52
h(t) total	7.56	1.21	1.08	2.31	2.17	2.45	8.58
dynamic head (metres)	5.65	0.91	0.84	0.69	0.60	0.77	0.53

flow rate q (gpm)	total dynamic head m	total static head m	total system head m	suction dynamic head m	suction static head m	suction system head m
0	0.00	34.20	34.20	0.00	3.45	3.45
250	0.14	34.20	34.33	0.12	3.45	3.57
500	0.54	34.20	34.74	0.46	3.45	3.91
750	1.22	34.20	35.42	1.04	3.45	4.49
1000	2.17	34.20	36.37	1.84	3.45	5.29
1250	3.39	34.20	37.58	2.88	3.45	6.33
1500	4.88	34.20	39.07	4.14	3.45	7.59
1750	6.64	34.20	40.84	5.64	3.45	9.09
2000	8.67	34.20	42.87	7.36	3.45	10.81
2250	10.97	34.20	45.17	9.32	3.45	12.77
2500	13.54	34.20	47.74	11.50	3.45	14.95
2750	16.39	34.20	50.59	13.92	3.45	17.37
3000	19.50	34.20	53.70	16.57	3.45	20.02

static total head = 34.1984

static suction head = 3.45156

pumping tank 2 or 3

1 Pump / 1 Tank

Trim in degs. = 3

flow rate q (gpm)	total system head: bellmouth	25%	50%	75%	90%	100%	suction system head: bellmouth	25%	50%	75%	90%	100%
0	34.20	32.31	30.53	28.67	27.20	23.82	3.45	1.56	-0.22	-2.08	-3.55	-6.93
250	34.33	32.44	30.66	28.80	27.33	23.95	3.57	1.68	-0.10	-1.96	-3.43	-6.81
500	34.74	32.85	31.07	29.21	27.74	24.36	3.91	2.02	0.24	-1.62	-3.09	-6.47
750	35.42	33.53	31.75	29.89	28.42	25.04	4.49	2.60	0.82	-1.04	-2.51	-5.89
1000	36.37	34.48	32.70	30.84	29.37	25.99	5.29	3.40	1.62	-0.24	-1.71	-5.09
1250	37.58	35.69	33.91	32.05	30.58	27.20	6.33	4.44	2.66	0.80	-0.67	-4.05
1500	39.07	37.18	35.40	33.54	32.07	28.69	7.59	5.70	3.92	2.06	0.59	-2.79
1750	40.84	38.95	37.17	35.31	33.84	30.46	9.09	7.20	5.42	3.56	2.09	-1.29
2000	42.87	40.98	39.20	37.34	35.87	32.49	10.81	8.92	7.14	5.28	3.81	0.43
2250	45.17	43.28	41.50	39.64	38.17	34.79	12.77	10.88	9.10	7.24	5.77	2.39
2500	47.74	45.85	44.07	42.21	40.74	37.36	14.95	13.06	11.28	9.42	7.95	4.57
2750	50.59	48.70	46.92	45.06	43.59	40.21	17.37	15.48	13.70	11.84	10.37	6.99
3000	53.70	51.81	50.03	48.17	46.70	43.32	20.02	18.13	16.35	14.49	13.02	9.64

TABLE 3

analysis of ocean ranger ballast system

calculation of total system and suction system heads   flow rate = 2300 gpm

description of pipe system	suction in pontoon	suction in pumproom	suction in manifold	suction in pumproom	suction in pumproom	discharge	discharge
length (metres)	78.25	1.80	2.60	2.40	0.95	3.90	49.03
diameter (m)	.2047	.2047	.4318	.4318	.254	.254	.381
velocity (m/s)	3.83	3.83	0.86	0.86	2.49	2.49	1.11
reynolds *10^-6	0.58	0.58	0.28	0.28	0.48	0.48	0.27
friction factor	.016	.016	.016	.016	.016	.016	.016
h(f) friction	6.12	0.14	0.10	0.09	0.06	0.25	2.06
h(c)constriction	1.44	1.07	0.90	2.22	2.11	2.20	6.52
h(t) total	7.56	1.21	1.00	2.31	2.17	2.45	8.58
dynamic head (metres)	5.65	0.91	0.04	0.09	0.68	0.77	0.53

flow rate q (gpm)	total dynamic head m	total static head m	total system head m	suction dynamic head m	suction static head m	suction system head m
0	0.00	36.45	36.45	0.00	6.07	6.07
250	0.14	36.45	36.58	0.12	6.07	6.19
500	0.54	36.45	36.99	0.46	6.07	6.53
750	1.22	36.45	37.66	1.04	6.07	7.11
1000	2.17	36.45	38.61	1.84	6.07	7.91
1250	3.39	36.45	39.83	2.88	6.07	8.95
1500	4.88	36.45	41.32	4.14	6.07	10.22
1750	6.64	36.45	43.08	5.64	6.07	11.71
2000	8.67	36.45	45.11	7.36	6.07	13.44
2250	10.97	36.45	47.42	9.32	6.07	15.39
2500	13.54	36.45	49.99	11.50	6.07	17.58
2750	16.39	36.45	52.83	13.92	6.07	19.99
3000	19.50	36.45	55.95	16.57	6.07	22.64

static total head = 36.4456   static suction head = 6.07307

pumping tank 2 or 3

1 Pump / 1 Tank

Trim in degs. = 4

flow rate q (gpm)	total system head						suction system head					
	bellmouth	25%	50%	75%	90%	100%	bellmouth	25%	50%	75%	90%	100%
0	36.45	34.82	32.99	31.13	29.57	26.28	6.07	4.44	2.61	0.75	-0.81	-4.10
250	36.58	34.95	33.12	31.26	29.70	26.41	6.19	4.56	2.73	0.87	-0.69	-3.98
500	36.99	35.36	33.53	31.67	30.11	26.82	6.53	4.90	3.07	1.21	-0.35	-3.64
750	37.66	36.03	34.20	32.34	30.78	27.49	7.11	5.48	3.65	1.79	0.23	-3.06
1000	38.61	36.98	35.15	33.29	31.73	28.44	7.91	6.28	4.45	2.59	1.03	-2.26
1250	39.83	38.20	36.37	34.51	32.95	29.66	8.95	7.32	5.49	3.63	2.07	-1.22
1500	41.32	39.69	37.86	36.00	34.44	31.15	10.22	8.59	6.76	4.90	3.34	0.05
1750	43.08	41.45	39.62	37.76	36.20	32.91	11.71	10.08	8.25	6.39	4.83	1.54
2000	45.11	43.48	41.65	39.79	38.23	34.94	13.44	11.81	9.98	8.12	6.56	3.27
2250	47.42	45.79	43.96	42.10	40.54	37.25	15.39	13.76	11.93	10.07	8.51	5.22
2500	49.99	48.36	46.53	44.67	43.11	39.82	17.58	15.95	14.12	12.26	10.70	7.41
2750	52.83	51.20	49.37	47.51	45.95	42.66	19.99	18.36	16.53	14.67	13.11	9.82
3000	55.95	54.32	52.49	50.63	49.07	45.78	22.64	21.01	19.18	17.32	15.76	12.47

TABLE 4

analysis of ocean ranger ballast system

calculation of total system and suction system heads   flow rate = 2000 gpm

description of pipe system	suction in pontoon	suction in pumproom	suction in manifold	suction in pumproom	suction in pumproom	discharge	discharge
length (metres)	78.25	1.80	2.60	2.40	0.95	3.90	49.03
diameter (m)	.2047	.2047	.4318	.4318	.254	.254	.381
velocity (m/s)	3.83	3.83	0.86	0.86	2.49	2.49	1.11
reynolds *10^-6	0.58	0.58	0.28	0.28	0.48	0.48	0.27
friction factor	.016	.016	.016	.016	.016	.016	.016
h(f) friction	6.12	0.14	0.10	0.09	0.06	0.25	2.06
h(c)constriction	1.44	1.07	0.90	2.22	2.11	2.20	6.52
h(t) total	7.56	1.21	1.00	2.31	2.17	2.45	8.58
dynamic head (metres)	5.65	0.91	0.04	0.09	0.68	0.77	0.53

flow rate q (gpm)	total dynamic head m	total static head m	total system head m	suction dynamic head m	suction static head m	suction system head m
0	0.00	38.65	38.65	0.00	8.69	8.69
250	0.14	38.65	38.78	0.12	8.69	8.80
500	0.54	38.65	39.19	0.46	8.69	9.15
750	1.22	38.65	39.87	1.04	8.69	9.72
1000	2.17	38.65	40.82	1.84	8.69	10.53
1250	3.39	38.65	42.03	2.88	8.69	11.56
1500	4.88	38.65	43.52	4.14	8.69	12.83
1750	6.64	38.65	45.29	5.64	8.69	14.33
2000	8.67	38.65	47.32	7.36	8.69	16.05
2250	10.97	38.65	49.62	9.32	8.69	18.01
2500	13.54	38.65	52.19	11.50	8.69	20.19
2750	16.39	38.65	55.04	13.92	8.69	22.61
3000	19.50	38.65	58.15	16.57	8.69	25.26

static total head = 38.6482   static suction head = 8.68881

pumping tank 2 or 3

1 Pump / 1 Tank

Trim in degs. = 6

flow rate q (gpm)	total system head						suction system head					
	bellmouth	25%	50%	75%	90%	100%	bellmouth	25%	50%	75%	90%	100%
0	38.65	37.23	35.45	33.62	31.87	28.68	8.69	7.27	5.49	3.66	1.91	-1.28
250	38.78	37.36	35.58	33.75	32.00	28.81	8.80	7.38	5.60	3.77	2.02	-1.17
500	39.19	37.77	35.99	34.16	32.41	29.22	9.15	7.73	5.95	4.12	2.37	-0.82
750	39.87	38.45	36.67	34.84	33.09	29.90	9.72	8.30	6.52	4.69	2.94	-0.25
1000	40.82	39.40	37.62	35.79	34.04	30.85	10.53	9.11	7.33	5.50	3.75	0.56
1250	42.03	40.61	38.83	37.00	35.25	32.06	11.56	10.14	8.36	6.53	4.78	1.59
1500	43.52	42.10	40.32	38.49	36.74	33.55	12.83	11.41	9.63	7.80	6.05	2.86
1750	45.29	43.87	42.09	40.26	38.51	35.32	14.33	12.91	11.13	9.30	7.55	4.36
2000	47.32	45.90	44.12	42.29	40.54	37.35	16.05	14.63	12.85	11.02	9.27	6.08
2250	49.62	48.20	46.42	44.59	42.84	39.65	18.01	16.59	14.81	12.98	11.23	8.04
2500	52.19	50.77	48.99	47.16	45.41	42.22	20.19	18.77	16.99	15.16	13.41	10.22
2750	55.04	53.62	51.84	50.01	48.26	45.07	22.61	21.19	19.41	17.58	15.83	12.64
3000	58.15	56.73	54.95	53.12	51.37	48.18	25.26	23.84	22.06	20.23	18.48	15.29

TABLE 5

analysis of ocean ranger ballast system
****

calculation of total system and suction system heads   flow rate = 2000 gpm

description of pipe system	suction in pontoon	suction in pumproom	suction in manifold	suction in pumproom	suction in pumproom	discharge	discharge
length [metres]	78.25	1.80	2.40	2.40	0.95	3.90	49.00
diameter (m)	.2047	.2047	.4318	.4318	.254	.254	.361
velocity [m/s]	3.83	3.83	0.86	0.86	2.49	2.49	1.11
reynolds *10^-6	0.58	0.58	0.24	0.24	0.48	0.48	0.27
friction factor	.016	.016	.016	.016	.016	.016	.016
h(f) friction	4.12	0.14	0.10	0.09	0.06	0.25	2.06
h(c)constriction	1.44	1.07	0.98	2.22	2.11	2.20	6.52
h(t) total	7.56	1.21	1.08	2.31	2.17	2.45	8.58
dynamic head [metres]	5.65	0.91	0.84	0.89	0.60	0.77	0.33

flow rate q (gpm)	total dynamic head m	total static head m	total system head m	suction dynamic head m	suction static head m	suction system head m
0	0.00	40.80	40.80	0.00	11.29	11.29
250	0.14	40.80	40.94	0.12	11.29	11.41
500	0.54	40.80	41.35	0.46	11.29	11.75
750	1.22	40.80	42.02	1.04	11.29	12.33
1000	2.17	40.80	42.97	1.84	11.29	13.13
1250	3.39	40.80	44.19	2.88	11.29	14.17
1500	4.88	40.80	45.68	4.14	11.29	15.43
1750	6.64	40.80	47.44	5.64	11.29	16.93
2000	8.67	40.80	49.47	7.36	11.29	18.66
2250	10.97	40.80	51.77	9.32	11.29	20.61
2500	13.54	40.80	54.35	11.50	11.29	22.80
2750	16.39	40.80	57.19	13.92	11.29	25.21
3000	19.50	40.80	60.31	16.57	11.29	27.86

static total head
= 40.8037

static suction head
= 11.2932

pumping tank 2 or 3

1 Pump / 1 Tank

Trim in degs. = 0

flow rate q (gpm)	total system head						suction system head					
	bellmouth	25%	50%	75%	90%	100%	bellmouth	25%	50%	75%	90%	100%
0	40.80	39.61	37.83	35.98	34.12	31.04	11.29	10.10	8.32	6.47	4.61	1.53
250	40.94	39.75	37.97	36.12	34.26	31.18	11.41	10.22	8.44	6.59	4.73	1.65
500	41.35	40.16	38.38	36.53	34.67	31.59	11.75	10.56	8.78	6.93	5.07	1.99
750	42.02	40.83	39.05	37.20	35.34	32.26	12.33	11.14	9.36	7.51	5.65	2.57
1000	42.97	41.78	40.00	38.15	36.29	33.21	13.13	11.94	10.16	8.31	6.45	3.37
1250	44.19	43.00	41.22	39.37	37.51	34.43	14.17	12.98	11.20	9.35	7.49	4.41
1500	45.68	44.49	42.71	40.86	39.00	35.92	15.43	14.24	12.46	10.61	8.75	5.67
1750	47.44	46.25	44.47	42.62	40.76	37.68	16.93	15.74	13.96	12.11	10.25	7.17
2000	49.47	48.28	46.50	44.65	42.79	39.71	18.66	17.47	15.69	13.84	11.98	8.90
2250	51.77	50.58	48.80	46.95	45.09	42.01	20.61	19.42	17.64	15.79	13.93	10.85
2500	54.35	53.16	51.38	49.53	47.67	44.59	22.80	21.61	19.83	17.98	16.12	13.04
2750	57.19	56.00	54.22	52.37	50.51	47.43	25.21	24.02	22.24	20.39	18.53	15.45
3000	60.31	59.12	57.34	55.49	53.63	50.55	27.86	26.67	24.89	23.04	21.18	18.10

TABLE 6

analysis of ocean ranger ballast system
****

calculation of total system and suction system heads   flow rate = 2000 gpm

description of pipe system	suction in pontoon	suction in pumproom	suction in manifold	suction in pumproom	suction in pumproom	discharge	discharge
length [metres]	73.25	1.80	2.60	2.40	0.95	3.90	49.03
diameter (m)	.2047	.2047	.4318	.4318	.254	.254	.381
velocity [m/s]	3.83	3.83	0.86	0.86	2.49	2.49	1.11
reynolds *10^-6	0.58	0.58	0.24	0.24	0.48	0.48	0.27
friction factor	.016	.016	.016	.016	.016	.016	.016
h(f) friction	4.12	0.14	0.10	0.09	0.06	0.25	2.06
h(c)constriction	1.44	1.07	0.98	2.22	2.11	2.20	6.52
h(t) total	7.56	1.21	1.08	2.31	2.17	2.45	8.58
dynamic head [metres]	5.65	0.91	0.84	0.89	0.60	0.77	0.33

flow rate q (gpm)	total dynamic head m	total static head m	total system head m	suction dynamic head m	suction static head m	suction system head m
0	0.00	42.91	42.91	0.00	13.88	13.88
250	0.14	42.91	43.04	0.12	13.88	14.00
500	0.54	42.91	43.45	0.46	13.88	14.34
750	1.22	42.91	44.13	1.04	13.88	14.92
1000	2.17	42.91	45.08	1.84	13.88	15.72
1250	3.39	42.91	46.30	2.88	13.88	16.76
1500	4.88	42.91	47.79	4.14	13.88	18.03
1750	6.64	42.91	49.55	5.64	13.88	19.52
2000	8.67	42.91	51.58	7.36	13.88	21.25
2250	10.97	42.91	53.88	9.32	13.88	23.20
2500	13.54	42.91	56.45	11.50	13.88	25.39
2750	16.39	42.91	59.30	13.92	13.88	27.80
3000	19.50	42.91	62.41	16.57	13.88	30.45

static total head
= 42.9095

static suction head
= 13.8838

pumping tank 2 or 3

1 Pump / 1 Tank

Trim in degs. = 10

flow rate q (gpm)	total system head						suction system head					
	bellmouth	25%	50%	75%	90%	100%	bellmouth	25%	50%	75%	90%	100%
0	42.91	41.94	40.14	38.29	36.29	33.35	13.88	12.91	11.11	9.26	7.26	4.32
250	43.04	42.07	40.27	38.42	36.42	33.48	14.00	13.03	11.23	9.38	7.38	4.44
500	43.45	42.48	40.68	38.83	36.83	33.89	14.34	13.37	11.57	9.72	7.72	4.78
750	44.13	43.16	41.36	39.51	37.51	34.57	14.92	13.95	12.15	10.30	8.30	5.36
1000	45.08	44.11	42.31	40.46	38.46	35.52	15.72	14.75	12.95	11.10	9.10	6.16
1250	46.30	45.33	43.53	41.68	39.68	36.74	16.76	15.79	13.99	12.14	10.14	7.20
1500	47.79	46.82	45.02	43.17	41.17	38.23	18.03	17.06	15.26	13.41	11.41	8.47
1750	49.55	48.58	46.78	44.93	42.93	39.99	19.52	18.55	16.75	14.90	12.90	9.96
2000	51.58	50.61	48.81	46.96	44.96	42.02	21.25	20.28	18.48	16.63	14.63	11.69
2250	53.88	52.91	51.11	49.26	47.26	44.32	23.20	22.23	20.43	18.58	16.58	13.64
2500	56.45	55.48	53.68	51.83	49.83	46.89	25.39	24.42	22.62	20.77	18.77	15.83
2750	59.30	58.33	56.53	54.68	52.68	49.74	27.80	26.83	25.03	23.18	21.18	18.24
3000	62.41	61.44	59.64	57.79	55.79	52.85	30.45	29.48	27.68	25.83	23.83	20.89

TABLE 7

analysis of ocean ranger ballast system
======================================

calculation of total system and suction system heads   flow rate = 2000 gpm

description of pipe system	suction in pontoon	suction in pumproom	suction in manifold	suction in pumproom	suction in pumproom	discharge	discharge
length (metres)	78.25	1.83	2.60	2.46	0.95	3.90	49.00
diameter (m)	.2047	.2047	.4318	.4318	.254	.254	.301
velocity (m/s)	3.83	3.83	0.86	0.86	2.49	2.49	1.11
reynolds *10^-6	0.58	0.58	0.24	0.24	0.48	0.48	0.27
friction factor	.016	.016	.016	.016	.016	.016	.016
h(f) friction	6.12	0.14	0.10	0.09	0.06	0.25	2.06
h(c)constriction	1.44	1.07	0.90	2.22	2.11	2.20	6.52
h(t) total	7.56	1.21	1.00	2.31	2.17	2.45	8.58
dynamic head (metres)	5.65	0.91	0.04	0.09	0.60	0.77	0.53

flow rate q (gpm)	total dynamic head m	total static head m	total system head m	suction dynamic head m	suction static head m	suction system head m
0	0.00	44.96	44.96	0.00	16.46	16.46
250	0.14	44.96	45.10	0.12	16.46	16.57
500	0.54	44.96	45.50	0.46	16.46	16.92
750	1.22	44.96	46.18	1.04	16.46	17.49
1000	2.17	44.96	47.13	1.84	16.46	18.30
1250	3.39	44.96	48.35	2.88	16.46	19.33
1500	4.88	44.96	49.84	4.14	16.46	20.60
1750	6.64	44.96	51.60	5.64	16.46	22.09
2000	8.67	44.96	53.63	7.36	16.46	23.82
2250	10.97	44.96	55.93	9.32	16.46	25.78
2500	13.54	44.96	58.51	11.50	16.46	27.96
2750	16.39	44.96	61.35	13.92	16.46	30.38
3000	19.50	44.96	64.47	16.57	16.46	33.02

static total head = 44.9631

static suction head = 16.4574

pumping tank 2 or 3

1 Pump / 1 Tank

Trim in degs. = 12

flow rate q (gpm)	total system head: bellmouth	25%	50%	75%	90%	100%	suction system head: bellmouth	25%	50%	75%	90%	100%
0	44.96	44.26	42.44	40.56	38.41	35.61	16.46	15.76	13.94	12.06	9.91	7.11
250	45.10	44.40	42.58	40.70	38.55	35.75	16.57	15.87	14.05	12.17	10.02	7.22
500	45.50	44.80	42.98	41.10	38.95	36.15	16.92	16.22	14.40	12.52	10.37	7.57
750	46.18	45.48	43.66	41.78	39.63	36.83	17.49	16.79	14.97	13.09	10.94	8.14
1000	47.13	46.43	44.61	42.73	40.58	37.78	18.30	17.60	15.78	13.90	11.75	8.95
1250	48.35	47.65	45.83	43.95	41.80	39.00	19.33	18.63	16.81	14.93	12.78	9.98
1500	49.84	49.14	47.32	45.44	43.29	40.49	20.60	19.90	18.08	16.20	14.05	11.25
1750	51.60	50.90	49.08	47.20	45.05	42.25	22.09	21.39	19.57	17.69	15.54	12.74
2000	53.63	52.93	51.11	49.23	47.08	44.28	23.82	23.12	21.30	19.42	17.27	14.47
2250	55.93	55.23	53.41	51.53	49.38	46.58	25.78	25.08	23.26	21.38	19.23	16.43
2500	58.51	57.81	55.99	54.11	51.96	49.16	27.96	27.26	25.44	23.56	21.41	18.61
2750	61.35	60.65	58.83	56.95	54.80	52.00	30.38	29.69	27.86	25.98	23.83	21.03
3000	64.47	63.77	61.95	60.07	57.92	55.12	33.02	32.32	30.50	28.62	26.47	23.67

TABLE 8

analysis of ocean ranger ballast system
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calculation of total system and suction system heads   flow rate = 2000 gpm

description of pipe system	suction in pontoon	suction in pumproom	suction in manifold	suction in pumproom	suction in pumproom	discharge	discharge
length (metres)	156.50	3.40	5.23	2.48	0.95	3.90	49.00
diameter (m)	.2047	.2047	.4318	.4318	.254	.254	.301
velocity (m/s)	1.91	1.91	0.43	0.86	2.49	2.49	1.11
reynolds *10^-6	0.25	0.25	0.12	0.24	0.48	0.48	0.27
friction factor	.017	.017	.018	.016	.016	.016	.016
h(f) friction	13.00	0.30	0.22	0.09	0.06	0.25	2.06
h(c)constriction	2.08	2.14	1.80	2.22	2.11	2.20	6.52
h(t) total	15.08	2.44	2.02	2.31	2.17	2.45	8.58
dynamic head (metres)	2.97	0.46	0.02	0.09	0.60	0.77	0.53

flow rate q (gpm)	total dynamic head m	total static head m	total system head m	suction dynamic head m	suction static head m	suction system head m
0	0.00	31.91	31.91	0.00	0.83	0.83
250	0.09	31.91	32.00	0.07	0.83	0.89
500	0.34	31.91	32.25	0.26	0.83	1.09
750	0.78	31.91	32.69	0.59	0.83	1.42
1000	1.38	31.91	33.29	1.05	0.83	1.88
1250	2.16	31.91	34.07	1.65	0.83	2.47
1500	3.10	31.91	35.01	2.37	0.83	3.20
1750	4.23	31.91	36.14	3.23	0.83	4.05
2000	5.52	31.91	37.43	4.21	0.83	5.04
2250	6.99	31.91	38.90	5.33	0.83	6.16
2500	8.62	31.91	40.53	6.58	0.83	7.41
2750	10.43	31.91	42.34	7.97	0.83	8.79
3000	12.42	31.91	44.33	9.48	0.83	10.31

static total head = 31.91

static suction head = .825

pumping tanks 2 + 3

1 Pump / 2 Tanks

Trim in degs. = 3

flow rate q (gpm)	total system head: bellmouth	25%	50%	75%	90%	100%	suction system head: bellmouth	25%	50%	75%	90%	100%
0	31.91	29.81	28.06	26.13	24.79	21.33	0.83	-1.28	-3.03	-4.96	-6.30	-9.76
250	32.00	29.90	28.15	26.22	24.88	21.42	0.89	-1.21	-2.96	-4.89	-6.23	-9.69
500	32.25	30.15	28.40	26.47	25.13	21.67	1.09	-1.01	-2.76	-4.69	-6.03	-9.49
750	32.69	30.59	28.84	26.91	25.57	22.11	1.42	-0.68	-2.43	-4.36	-5.70	-9.16
1000	33.29	31.19	29.44	27.51	26.17	22.71	1.88	-0.22	-1.97	-3.90	-5.24	-8.70
1250	34.07	31.97	30.22	28.29	26.95	23.49	2.47	0.37	-1.38	-3.31	-4.65	-8.11
1500	35.01	32.91	31.16	29.23	27.89	24.43	3.20	1.10	-0.65	-2.58	-3.92	-7.38
1750	36.14	34.04	32.29	30.36	29.02	25.56	4.05	1.95	0.20	-1.73	-3.07	-6.53
2000	37.43	35.33	33.58	31.65	30.31	26.85	5.04	2.94	1.19	-0.74	-2.08	-5.54
2250	38.90	36.80	35.05	33.12	31.78	28.32	6.16	4.06	2.31	0.38	-0.96	-4.42
2500	40.53	38.43	36.68	34.75	33.41	29.95	7.41	5.31	3.56	1.63	0.29	-3.17
2750	42.34	40.24	38.49	36.56	35.22	31.76	8.79	6.69	4.94	3.01	1.67	-1.79
3000	44.33	42.23	40.48	38.55	37.21	33.75	10.31	8.21	6.46	4.52	3.19	-0.27

TABLE 9

analysis of ocean ranger ballast system

calculation of total system and suction system heads   flow rate = 2000 gpm

description of pipe system	suction in pontoon	suction in pumproom	suction in manifold	suction in pumproom	suction in pumproom	discharge	discharge
length (metres)	156.50	3.60	5.20	2.40	0.95	3.90	49.00
diameter (m)	.2047	.2047	.4318	.4318	.254	.254	.381
velocity (m/s)	1.91	1.91	0.43	0.86	2.49	2.49	1.11
reynolds *10^-6	0.25	0.25	0.12	0.24	0.40	0.40	0.27
friction factor	.017	.017	.018	.016	.014	.016	.016
k(f) friction	13.00	0.30	0.22	0.09	0.06	0.25	2.06
k(c)constriction	2.00	2.14	1.80	2.22	2.11	2.20	6.52
k(t) total	15.00	2.44	2.02	2.31	2.17	2.45	8.58
dynamic head (metres)	2.97	0.46	0.02	0.09	0.68	0.77	0.53

flow rate q (gpm)	total dynamic head m	total static head m	total system head m	suction dynamic head m	suction static head m	suction system head m
0	0.00	34.20	34.20	0.00	3.45	3.45
250	0.09	34.20	34.28	0.07	3.45	3.52
500	0.34	34.20	34.54	0.26	3.45	3.71
750	0.78	34.20	34.97	0.59	3.45	4.04
1000	1.38	34.20	35.58	1.05	3.45	4.50
1250	2.16	34.20	36.35	1.65	3.45	5.10
1500	3.10	34.20	37.30	2.37	3.45	5.82
1750	4.23	34.20	38.42	3.23	3.45	6.68
2000	5.52	34.20	39.72	4.21	3.45	7.67
2250	6.99	34.20	41.18	5.33	3.45	8.78
2500	8.62	34.20	42.82	6.58	3.45	10.04
2750	10.43	34.20	44.63	7.97	3.45	11.42
3000	12.42	34.20	46.62	9.48	3.45	12.93

static total head = 34.1906

static suction head = 3.45154

pumping tanks 2 + 3

1 Pump / 2 Tanks

Trim in degs. = 2

flow rate q (gpm)	total system head						suction system head					
	bellmouth	25%	50%	75%	90%	100%	bellmouth	25%	50%	75%	90%	100%
0	34.20	32.31	30.53	28.67	27.20	23.82	3.45	1.56	-0.22	-2.08	-3.55	-6.93
250	34.28	32.39	30.61	28.75	27.28	23.90	3.52	1.63	-0.15	-2.01	-3.48	-6.86
500	34.54	32.65	30.87	29.01	27.54	24.16	3.71	1.82	0.04	-1.82	-3.29	-6.67
750	34.97	33.08	31.30	29.44	27.97	24.59	4.04	2.15	0.37	-1.49	-2.96	-6.34
1000	35.58	33.69	31.91	30.05	28.58	25.20	4.50	2.61	0.83	-1.03	-2.50	-5.88
1250	36.35	34.46	32.68	30.82	29.35	25.97	5.10	3.21	1.43	-0.43	-1.90	-5.28
1500	37.30	35.41	33.63	31.77	30.30	26.92	5.82	3.93	2.15	0.29	-1.18	-4.56
1750	38.42	36.53	34.75	32.89	31.42	28.04	6.68	4.79	3.01	1.15	-0.32	-3.70
2000	39.72	37.83	36.05	34.19	32.72	29.34	7.67	5.78	4.00	2.14	0.67	-2.71
2250	41.18	39.29	37.51	35.65	34.18	30.80	8.78	6.89	5.11	3.25	1.78	-1.60
2500	42.82	40.93	39.15	37.29	35.82	32.44	10.04	8.15	6.37	4.51	3.04	-0.34
2750	44.63	42.74	40.96	39.10	37.63	34.25	11.42	9.53	7.75	5.89	4.42	1.04
3000	46.62	44.73	42.95	41.09	39.62	36.24	12.93	11.04	9.26	7.40	5.93	2.55

TABLE 10

analysis of ocean ranger ballast system

calculation of total system and suction system heads   flow rate = 2000 gpm

description of pipe system	suction in pontoon	suction in pumproom	suction in manifold	suction in pumproom	suction in pumproom	discharge	discharge
length (metres)	156.50	3.60	5.20	2.40	0.95	3.90	49.00
diameter (m)	.2047	.2047	.4318	.4318	.254	.254	.381
velocity (m/s)	1.91	1.91	0.43	0.86	2.49	2.49	1.11
reynolds *10^-6	0.25	0.25	0.12	0.24	0.40	0.40	0.27
friction factor	.017	.017	.018	.016	.016	.016	.016
k(f) friction	13.00	0.30	0.22	0.09	0.06	0.25	2.06
k(c)constriction	2.00	2.14	1.80	2.22	2.11	2.20	6.52
k(t) total	15.00	2.44	2.02	2.31	2.17	2.45	8.58
dynamic head (metres)	2.97	0.46	0.02	0.09	0.68	0.77	0.53

flow rate q (gpm)	total dynamic head m	total static head m	total system head m	suction dynamic head m	suction static head m	suction system head m
0	0.00	36.45	36.45	0.00	6.07	6.07
250	0.09	36.45	36.53	0.07	6.07	6.14
500	0.34	36.45	36.79	0.26	6.07	6.34
750	0.78	36.45	37.22	0.59	6.07	6.67
1000	1.38	36.45	37.83	1.05	6.07	7.13
1250	2.16	36.45	38.60	1.65	6.07	7.72
1500	3.10	36.45	39.55	2.37	6.07	8.44
1750	4.23	36.45	40.67	3.23	6.07	9.30
2000	5.52	36.45	41.96	4.21	6.07	10.29
2250	6.99	36.45	43.43	5.33	6.07	11.41
2500	8.62	36.45	45.07	6.58	6.07	12.66
2750	10.43	36.45	46.88	7.97	6.67	14.04
3000	12.42	36.45	48.86	9.48	6.07	15.55

static total head = 36.4456

static suction head = 6.07307

pumping tanks 2 + 3

1 Pump / 2 Tanks

Trim in degs. = 4

flow rate q (gpm)	total system head						suction system head					
	bellmouth	25%	50%	75%	90%	100%	bellmouth	25%	50%	75%	90%	100%
0	36.45	34.82	32.99	31.13	29.57	26.28	6.07	4.44	2.61	0.75	-0.81	-4.10
250	36.53	34.90	33.07	31.21	29.65	26.36	6.14	4.51	2.68	0.82	-0.74	-4.03
500	36.79	35.16	33.33	31.47	29.91	26.62	6.34	4.71	2.88	1.02	-0.54	-3.83
750	37.22	35.59	33.76	31.90	30.34	27.05	6.67	5.04	3.21	1.35	-0.21	-3.50
1000	37.83	36.20	34.37	32.51	30.95	27.66	7.13	5.50	3.67	1.81	0.25	-3.04
1250	38.60	36.97	35.14	33.28	31.72	28.43	7.72	6.09	4.26	2.40	0.84	-2.45
1500	39.55	37.92	36.09	34.23	32.67	29.38	8.44	6.81	4.98	3.12	1.56	-1.73
1750	40.67	39.04	37.21	35.35	33.79	30.50	9.30	7.67	5.84	3.98	2.42	-0.87
2000	41.96	40.33	38.50	36.64	35.08	31.79	10.29	8.66	6.83	4.97	3.41	0.12
2250	43.43	41.80	39.97	38.11	36.55	33.26	11.41	9.78	7.95	6.09	4.53	1.24
2500	45.07	43.44	41.61	39.75	38.19	34.90	12.66	11.03	9.20	7.34	5.78	2.49
2750	46.88	45.25	43.42	41.56	40.00	36.71	14.04	12.41	10.58	8.72	7.16	3.87
3000	48.86	47.23	45.40	43.54	41.98	38.69	15.55	13.92	12.09	10.23	8.67	5.38

TABLE 11

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        analysis of ocean ranger ballast system
        ***************************************

calculation of total system and suction system heads    flow rate = 2000 gpm

description of    suction in   suction in   suction in   suction in   suction in   discharge   discharge
pipe system       pontoon      pumproom     manifold     pumproom     pumproom

length (metres)   156.50         3.40         5.20         2.40         0.95         3.90       49.00

diameter (m)       .2047         .2047        .4318        .4318        .254         .254        .381

velocity (m/s)     1.91          1.91         0.43         0.86         2.49         2.49        1.11
reynolds x10^-6    0.25          0.25         0.12         0.24         0.40         0.40        0.27
friction factor    .017          .017         .018         .016         .016         .016        .016
K(f) friction     13.00          0.30         0.22         0.09         0.06         0.25        2.06
K(c)constriction   2.00          2.14         1.80         2.22         2.11         2.20        6.52
=========================================================================================================
K(t) total        15.00          2.44         2.02         2.31         2.17         2.45        8.58
=========================================================================================================
dynamic head       2.97          0.46         0.02         0.09         0.68         0.77        0.53
(metres)


           :  total   total   total  suction suction suction
flow rate  :  dynamic static  system dynamic static  system
q (gpm)    :  head m  head m  head m head m  head m  head m          static total head      static suction head
           :                                                             = 38.6482               = 8.68881
     0     :    0.00   38.65   38.65   0.00   8.69    8.69
   250     :    0.09   38.65   38.73   0.07   8.69    8.75
   500     :    0.34   38.65   38.99   0.26   8.69    8.95
   750     :    0.78   38.65   39.42   0.59   8.69    9.28
  1000     :    1.38   38.65   40.03   1.05   8.69    9.74                  pumping tanks 2 + 3
  1250     :    2.16   38.65   40.80   1.65   8.69   10.33
  1500     :    3.10   38.65   41.75   2.37   8.69   11.06                  1 Pump / 2 Tanks
  1750     :    4.23   38.65   42.87   3.23   8.69   11.91
  2000     :    5.52   38.65   44.17   4.21   8.69   12.90                  Trim in degs. =  6
  2250     :    6.99   38.65   45.63   5.33   8.69   14.02
  2500     :    8.62   38.65   47.27   6.58   8.69   15.27
  2750     :   10.43   38.65   49.08   7.97   8.69   16.66
  3000     :   12.42   38.65   51.07   9.48   8.69   18.17


           :  --------------- total system head ------------   :  --------------- suction system head ----------
flow rate  :                                                    :
q (gpm)    : bellmouth   25%    50%    75%    90%    100%       : bellmouth   25%    50%    75%    90%    100%
           :                                                    :
     0     :   38.65   37.23  35.45  33.62  31.87  28.68        :    8.69    7.27   5.49   3.66   1.91  -1.28
   250     :   38.73   37.31  35.53  33.70  31.95  28.76        :    8.75    7.33   5.55   3.72   1.97  -1.22
   500     :   38.99   37.57  35.79  33.96  32.21  29.02        :    8.95    7.53   5.75   3.92   2.17  -1.02
   750     :   39.42   38.00  36.22  34.39  32.64  29.45        :    9.28    7.86   6.08   4.25   2.50  -0.69
  1000     :   40.03   38.61  36.83  35.00  33.25  30.06        :    9.74    8.32   6.54   4.71   2.96  -0.23
  1250     :   40.80   39.38  37.60  35.77  34.02  30.83        :   10.33    8.91   7.13   5.30   3.55   0.36
  1500     :   41.75   40.33  38.55  36.72  34.97  31.78        :   11.06    9.64   7.86   6.03   4.28   1.09
  1750     :   42.87   41.45  39.67  37.84  36.09  32.90        :   11.91   10.49   8.71   6.88   5.13   1.94
  2000     :   44.17   42.75  40.97  39.14  37.39  34.20        :   12.90   11.48   9.70   7.87   6.12   2.93
  2250     :   45.63   44.21  42.43  40.60  38.85  35.66        :   14.02   12.60  10.82   8.99   7.24   4.05
  2500     :   47.27   45.85  44.07  42.24  40.49  37.30        :   15.27   13.85  12.07  10.24   8.49   5.30
  2750     :   49.08   47.66  45.88  44.05  42.30  39.11        :   16.66   15.24  13.46  11.63   9.88   6.69
  3000     :   51.07   49.65  47.87  46.04  44.29  41.10        :   18.17   16.75  14.97  13.14  11.39   8.20
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TABLE 12

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        analysis of ocean ranger ballast system
        ***************************************

calculation of total system and suction system heads    flow rate = 2000 gpm

description of    suction in   suction in   suction in   suction in   suction in   discharge   discharge
pipe system       pontoon      pumproom     manifold     pumproom     pumproom

length (metres)   156.50         3.40         5.20         2.40         0.95         3.90       49.00

diameter (m)       .2047         .2047        .4318        .4318        .254         .254        .381

velocity (m/s)     1.91          1.91         0.43         0.86         2.49         2.49        1.11
reynolds x10^-6    0.25          0.25         0.12         0.24         0.40         0.40        0.27
friction factor    .017          .017         .018         .016         .016         .016        .016
K(f) friction     13.00          0.30         0.22         0.09         0.06         0.25        2.06
K(c)constriction   2.00          2.14         1.80         2.22         2.11         2.20        6.52
=========================================================================================================
K(t) total        15.00          2.44         2.02         2.31         2.17         2.45        8.58
=========================================================================================================
dynamic head       2.97          0.46         0.02         0.09         0.68         0.77        0.53
(metres)


           :  total   total   total  suction suction suction
flow rate  :  dynamic static  system dynamic static  system
q (gpm)    :  head m  head m  head m head m  head m  head m          static total head      static suction head
           :                                                             = 40.8037               = 11.2932
     0     :    0.00   40.80   40.80   0.00  11.29   11.29
   250     :    0.09   40.80   40.89   0.07  11.29   11.36
   500     :    0.34   40.80   41.15   0.26  11.29   11.56
   750     :    0.78   40.80   41.58   0.59  11.29   11.89
  1000     :    1.38   40.80   42.18   1.05  11.29   12.35                  pumping tanks 2 + 3
  1250     :    2.16   40.80   42.96   1.65  11.29   12.94
  1500     :    3.10   40.80   43.91   2.37  11.29   13.66                  1 Pump / 2 Tanks
  1750     :    4.23   40.80   45.03   3.23  11.29   14.52
  2000     :    5.52   40.80   46.32   4.21  11.29   15.51                  Trim in degs. =  0
  2250     :    6.99   40.80   47.79   5.33  11.29   16.63
  2500     :    8.62   40.80   49.43   6.58  11.29   17.88
  2750     :   10.43   40.80   51.24   7.97  11.29   19.26
  3000     :   12.42   40.80   53.22   9.48  11.29   20.77


           :  --------------- total system head ------------   :  --------------- suction system head ----------
flow rate  :                                                    :
q (gpm)    : bellmouth   25%    50%    75%    90%    100%       : bellmouth   25%    50%    75%    90%    100%
           :                                                    :
     0     :   40.80   39.61  37.83  35.98  34.12  31.04        :   11.29   10.10   8.32   6.47   4.61   1.53
   250     :   40.89   39.70  37.92  36.07  34.21  31.13        :   11.36   10.17   8.39   6.54   4.69   1.60
   500     :   41.15   39.96  38.18  36.33  34.47  31.39        :   11.56   10.37   8.59   6.74   4.89   1.80
   750     :   41.58   40.39  38.61  36.76  34.90  31.82        :   11.89   10.70   8.92   7.07   5.21   2.13
  1000     :   42.18   40.99  39.21  37.36  35.50  32.42        :   12.35   11.16   9.38   7.53   5.67   2.59
  1250     :   42.96   41.77  39.99  38.14  36.28  33.20        :   12.94   11.75   9.97   8.12   6.26   3.18
  1500     :   43.91   42.72  40.94  39.09  37.23  34.15        :   13.66   12.47  10.69   8.84   6.98   3.90
  1750     :   45.03   43.84  42.06  40.21  38.35  35.27        :   14.52   13.33  11.55   9.70   7.84   4.76
  2000     :   46.32   45.13  43.35  41.50  39.64  36.56        :   15.51   14.32  12.54  10.69   8.83   5.75
  2250     :   47.79   46.60  44.82  42.97  41.11  38.03        :   16.63   15.44  13.66  11.81   9.95   6.87
  2500     :   49.43   48.24  46.46  44.61  42.75  39.67        :   17.88   16.69  14.91  13.06  11.20   8.12
  2750     :   51.24   50.05  48.27  46.42  44.56  41.48        :   19.26   18.07  16.29  14.44  12.58   9.50
  3000     :   53.22   52.03  50.25  48.40  46.54  43.46        :   20.77   19.58  17.80  15.95  14.09  11.01
```

TABLE 13

analysis of ocean ranger ballast system

calculation of total system and suction system heads   flow rate = 2000 gpm

description of pipe system	suction in pontoon	suction in pumproom	suction in manifold	suction in pumproom	suction in pumproom	discharge	discharge
length (metres)	156.50	3.60	5.20	2.40	0.95	3.90	49.00
diameter (m)	.2047	.2047	.4318	.4318	.254	.254	.381
velocity (m/s)	1.91	1.91	0.43	0.86	2.49	2.49	1.11
reynolds *10^-6	0.25	0.25	0.12	0.24	0.48	0.48	0.27
friction factor	.017	.017	.018	.016	.016	.016	.014
K(f) friction	13.00	0.30	0.22	0.09	0.06	0.25	2.06
K(c)constriction	2.00	2.14	1.80	2.22	2.11	2.20	6.52
K(t) total	15.00	2.44	2.02	2.31	2.17	2.45	8.58
dynamic head (metres)	2.97	0.44	0.02	0.09	0.68	0.77	0.53

flow rate q (gpm)	total dynamic head m	total static head m	total system head m	suction dynamic head m	suction static head m	suction system head m
0	0.00	42.91	42.91	0.00	13.88	13.88
250	0.09	42.91	43.00	0.07	13.88	13.95
500	0.34	42.91	43.25	0.26	13.88	14.15
750	0.78	42.91	43.69	0.59	13.88	14.48
1000	1.38	42.91	44.29	1.05	13.88	14.94
1250	2.16	42.91	45.07	1.65	13.88	15.53
1500	3.10	42.91	46.01	2.37	13.88	16.25
1750	4.23	42.91	47.14	3.23	13.88	17.11
2000	5.52	42.91	48.43	4.21	13.88	18.10
2250	6.99	42.91	49.89	5.33	13.88	19.22
2500	8.62	42.91	51.53	6.58	13.88	20.47
2750	10.43	42.91	53.34	7.97	13.88	21.85
3000	12.42	42.91	55.33	9.48	13.88	23.36

static total head = 42.9095

static suction head = 13.8838

pumping tanks 2 + 3

1 Pump / 2 Tanks

Trim in degs. = 10

flow rate q (gpm)	total system head						suction system head					
	bellmouth	25%	50%	75%	90%	100%	bellmouth	25%	50%	75%	90%	100%
0	42.91	41.94	40.14	38.29	36.29	33.35	13.88	12.91	11.11	9.26	7.26	4.32
250	43.00	42.03	40.23	38.38	36.38	33.44	13.95	12.98	11.18	9.33	7.33	4.39
500	43.25	42.28	40.48	38.63	36.63	33.69	14.15	13.18	11.38	9.53	7.53	4.59
750	43.69	42.72	40.92	39.07	37.07	34.13	14.48	13.51	11.71	9.86	7.86	4.92
1000	44.29	43.32	41.52	39.67	37.67	34.73	14.94	13.97	12.17	10.32	8.32	5.38
1250	45.07	44.10	42.30	40.45	38.45	35.51	15.53	14.56	12.76	10.91	8.91	5.97
1500	46.01	45.04	43.24	41.39	39.39	36.45	16.25	15.28	13.48	11.63	9.63	6.69
1750	47.14	46.17	44.37	42.52	40.52	37.58	17.11	16.14	14.34	12.49	10.49	7.55
2000	48.43	47.46	45.66	43.81	41.81	38.87	18.10	17.13	15.33	13.48	11.48	8.54
2250	49.89	48.92	47.12	45.27	43.27	40.33	19.22	18.25	16.45	14.60	12.60	9.66
2500	51.53	50.56	48.76	46.91	44.91	41.97	20.47	19.50	17.70	15.85	13.85	10.91
2750	53.34	52.37	50.57	48.72	46.72	43.78	21.85	20.88	19.08	17.23	15.23	12.29
3000	55.33	54.36	52.56	50.71	48.71	45.77	23.36	22.39	20.59	18.74	16.74	13.80

TABLE 14

analysis of ocean ranger ballast system

calculation of total system and suction system heads   flow rate = 2000 gpm

description of pipe system	suction in pontoon	suction in pumproom	suction in manifold	suction in pumproom	suction in pumproom	discharge	discharge
length (metres)	156.50	3.60	5.20	2.40	0.95	3.90	47.00
diameter (m)	.2047	.2047	.4318	.4318	.254	.254	.381
velocity (m/s)	1.91	1.91	0.43	0.84	2.49	2.49	1.11
reynolds *10^-6	0.25	0.25	0.12	0.24	0.48	0.48	0.27
friction factor	.017	.017	.018	.016	.016	.016	.016
K(f) friction	13.00	0.30	0.22	0.09	0.06	0.25	2.06
K(c)constriction	2.00	2.14	1.80	2.22	2.11	2.20	6.52
K(t) total	15.00	2.44	2.02	2.31	2.17	2.45	8.58
dynamic head (metres)	2.97	0.46	0.02	0.09	0.68	0.77	0.53

flow rate q (gpm)	total dynamic head m	total static head m	total system head m	suction dynamic head m	suction static head m	suction system head m
0	0.00	44.96	44.96	0.00	16.46	16.46
250	0.09	44.96	45.05	0.07	16.46	16.52
500	0.34	44.96	45.31	0.26	16.46	16.72
750	0.78	44.96	45.74	0.59	16.46	17.05
1000	1.38	44.96	46.34	1.05	16.46	17.51
1250	2.16	44.96	47.12	1.65	16.46	18.10
1500	3.10	44.96	48.07	2.37	16.46	18.83
1750	4.23	44.96	49.19	3.23	16.46	19.68
2000	5.52	44.96	50.48	4.21	16.46	20.67
2250	6.99	44.96	51.95	5.33	16.46	21.79
2500	8.62	44.96	53.59	6.58	16.46	23.04
2750	10.43	44.96	55.40	7.97	16.46	24.42
3000	12.42	44.96	57.38	9.48	16.46	25.94

static total head = 44.9631

static suction head = 16.4574

pumping tanks 2 + 3

1 Pump / 2 Tanks

Trim in degs. = 12

flow rate q (gpm)	total system head						suction system head					
	bellmouth	25%	50%	75%	90%	100%	bellmouth	25%	50%	75%	90%	100%
0	44.96	44.26	42.44	40.56	38.41	35.61	16.46	15.76	13.94	12.06	9.91	7.11
250	45.05	44.35	42.53	40.65	38.50	35.70	16.52	15.82	14.00	12.12	9.97	7.17
500	45.31	44.61	42.79	40.91	38.76	35.96	16.72	16.02	14.20	12.32	10.17	7.37
750	45.74	45.04	43.22	41.34	39.19	36.39	17.05	16.35	14.53	12.65	10.50	7.70
1000	46.34	45.64	43.82	41.94	39.79	36.99	17.51	16.81	14.99	13.11	10.96	8.16
1250	47.12	46.42	44.60	42.72	40.57	37.77	18.10	17.40	15.58	13.70	11.55	8.75
1500	48.07	47.37	45.55	43.67	41.52	38.72	18.83	18.13	16.31	14.43	12.28	9.48
1750	49.19	48.49	46.67	44.79	42.64	39.84	19.68	18.98	17.16	15.28	13.13	10.33
2000	50.48	49.78	47.96	46.08	43.93	41.13	20.67	19.97	18.15	16.27	14.12	11.32
2250	51.95	51.25	49.43	47.55	45.40	42.60	21.79	21.09	19.27	17.39	15.24	12.44
2500	53.59	52.89	51.07	49.19	47.04	44.24	23.04	22.34	20.52	18.64	16.49	13.69
2750	55.40	54.70	52.88	51.00	48.85	46.05	24.42	23.72	21.90	20.02	17.87	15.07
3000	57.38	56.68	54.86	52.98	50.83	48.03	25.94	25.24	23.42	21.54	19.39	16.59

Item F-5
A Review of the *Ocean Ranger* Hydrodynamic Model Testing

It was recommended that model studies of the *Ocean Ranger* be undertaken to assist in examining the possible causes of the disaster. This suggestion was weighed against time domain computer simulations and was judged to have certain distinct advantages. These advantages included a more accurate simulation of the mooring system, breaking waves, chain locker flooding, ballast valve runaway, behaviour at large trim angles, flooding of the deckhouse and dragging of the anchors.

The choice of scale for the test was considered very carefully and was established at 1:40 in order to minimize scale effects. It was also concluded that such a large model would facilitate internal water ballast transfer, modelling of chain locker flooding and simulation of the mooring system, including breaking and dragging. The disadvantage of such a scale was that the mooring pattern became immense, even if not taken right out to the anchors but only well past the touch down points.

Technical and commercial proposals were sought from a number of basins in Canada, the United States, Britain, The Netherlands, Denmark, Sweden and Norway. The two basins that best fulfilled the technical requirements of the Commission were the Norwegian Hydrodynamics Laboratory (NHL) at Trondheim and the Hydraulics Laboratory of the National Research Council of Canada (NRC) at Ottawa. The basins were able to work with the model scale of 1:40 and were able to provide teams of highly qualified and experienced technical personnel. The Norwegian laboratory had an extensive track record of contract semisubmersible model testing experience and the Canadian laboratory was internationally known for its work on realistic simulation of wave conditions.

The decision to employ two wave basins, provided the advantage of cross-checks on a number of parallel results. NHL was able to offer the possibility of tests being run at 400 ft. depth as well as two-directional waves. These two features were not available at NRC. Certain other differences existed between the two laboratories. The first major difference was that NRC felt that it was necessary to reproduce the Smoothed Instantaneous Wave Energy History (SIWEH) distribution as well as the wave spectra from the time series obtained from the *Zapata Ugland* wave rider buoy. NHL on the other hand were of the opinion that wave grouping was a function of the peakedness of the spectrum and hence by producing the correct spectra they would automatically reproduce the groupiness.

The other major difference in approach between the two laboratories was in the use of results from the wind tunnel testing carried out by the National Aeronautical Establishment (NAE). NRC used loading filaments attached to the model, the forces in which were computer controlled to model the force and moment spectra. NHL used computer programmed speed controlled fans to apply the force, and hence moments, to the model directly as wind loads.

A number of investigations were required to precede the hydrodynamic model tests. One of these studies, conducted at NRC, was the hydraulic modelling of chain locker flooding. It was realized from the beginning that downflooding due to forward chain locker flooding would play a major role in the behaviour of the rig at large angles of trim, and probably in the subsequent capsize. The flooding of the chain lockers by waves breaking onto the deck and water flooding down the navel pipes is a complex phenomena governed by Froude, Reynolds and Weber number scaling laws. To reduce scale effects a 1:15 model of the forward column SC1, the deck facilities of which could easily be converted to simulate the mirror image arrangement of column PC1, was built. The deck items and all six chain locker openings on the column-deck and the associated navel pipes were modelled in detail.

Wave and rig motions were simulated by repeatedly immersing the model in still water, for various depths and periods of submergence, by means of a hydraulic actuator (Fig. 1). After measuring flooding rates using the 1:15 model, a 1:40 scale model was tested in the same manner to determine the single navel pipe size required to model the flooding rates correctly. A set of different initial pitch angles and depths of water over the deck for several time cycles was investigated for both models. An orifice was found that gave similar flooding rates through the single navel pipe in the 1:40 model to that of the six navel pipes in the 1:15 model. Few immersions were required at large trim angles to fill the chain lockers and navel pipes. When full, almost 1,200 tons (1,219 tonnes) of water are contained in either SC1 or PC1 chain lockers and navel pipes.

Another important study, conducted prior to the hydrodynamic test program, was the aerodynamic model test series, (Fig. 2). The National Aeronautical Establishment (NAE) of NRC used a 1:100 scale model to determine the mean and fluctuating components of the wind loads. Force and moment data were measured for various combinations of vessel attitude, draft and wind directions. A complete dynamic analysis of the model was carried out, using the structural analysis computer program SAP4, to ensure that the lowest natural frequency of the model was sufficiently high. The fabrication of the major structural components of the model from thin wall aluminum and deck fittings from wood and styrofoam kept the mass of the model, including the mounting beams, to 33 lb. (15 kg). The existing balance of the 30 ft. x 30 ft. (9 m x 9 m) wind tunnel of NAE at Uplands was judged to be unsatisfactory for tests of fluctuating loads on the extremely light model. A new dynamic six degree of freedom balance was designed, built, calibrated and used to measure all force and moment data.

Values of wind speed and direction for the storm were provided in the synoptic weather reports from the *Zapata Ugland*, the *SEDCO 706* and the *Ocean Ranger* (last report of the latter at 2330 NST). Values of the parameters were also available from the hindcast study by V.J. Cardone of Oceanweather Inc. made available by Mobil Oil (Canada) Ltd.

Estimates of the effects of waves on the wind loads were measured using stationary, rigid waves mounted on the floor of the wind tunnel. These simulated waves had prototype wave heights of 59 ft. (19 m) and wave lengths of 1312 ft. (400 m). Forces and moments for the model were measured in a number of positions relative to wave crest. The profile of the main wind speed, the turbulence intensity, turbulence scale and frequency content of the turbulence were modelled to simulate the conditions preceding and at the time of the capsize. Most of the wind tunnel data were collected for wind directions between 220° and 310°, for drafts between 32.8 ft. (10 m) and 131.2 ft. (40 m), and for pitch and roll angles between -20° to +20°. The spectra of drag forces, lift forces and overturning moments for several tests were compared. From the analysis, average spectra for the drag force, the lift force and overturning moment were obtained (the other degrees of freedom contained only small fluctuating components). These average spectra were used as models for the spectra of the wind loads to be applied.

Based on the test data, numerical models for predicting coefficients for drag, drag standard deviation, lift, lift standard deviation, overturning moment and overturning moment standard deviation were developed using multiple linear regression techniques. These results were given to the Hydraulics Laboratory (NRC), but were obtained too late for the initial use of NHL. Analytical gust spectra, due to Van Karman, were initially supplied to NHL.

A third study preceding the hydrodynamic model was also conducted at NRC. This study was undertaken to investigate the possibility of realistic simulation of the sea state at the time of the accident. The only wave data available from this time came from the *Zapata Ugland* site, 20 nautical miles away from the *Ocean Ranger*. In order to see if this data could be used with reasonable confidence as being representative for the *Ocean Ranger* site at the time of the disaster, data from the three rig sites at an earlier date were analyzed.

Records from the site of the *SEDCO 706*, the *Zapata Ugland* and the *Ocean Ranger* for the period between 16 to 20 January 1982 and 1 to 2 February 1982 were subjected to spectral and zero crossing analysis. The objective of this analysis was to establish that while all three stations were recording more or less concurrently, the average statistical descriptions of the sea state were sufficiently similar. If this could be shown, then it could be reasonably assumed that the sea state analysis from the *Zapata Ugland* at the time of the disaster would be descriptive for the sea state which prevailed at the *Ocean Ranger* site during the same time period.

The results of the analysis indicated that all wave parameters (without mean values removed) showed extremely high correlation. The day to day variations in sea state parameters about the mean, showed high cross-correlations for wind direction, wind velocity, wave power and characteristic wave height, and moderately high correlations for maximum wave height, peak period, peakedness factor and average steepness. However, the variational cross-correlations for the maximum to significant wave height ratio, the groupiness factor and the average horizontal wave asymmetry are almost zero.

Having established that the *Zapata Ugland* wave recording could be trusted to supply fairly reliable parameter descriptions of the sea state for westerly winds and significant wave heights greater than 5 m, at the *Ocean Ranger* site, NRC undertook a wave synthesis. The simulation was undertaken for the storm of the night of 14 February 1982 from 1830 NST to 15 February at 0430 NST. NRC re-analyzed the data and provided ten variance spectral densities for the ten consecutive hours. These ten spectra were then used by both NHL and by NRC to form ten separate one hour full-scale records, equivalent to ten separate 9 minute 29 second records in model scale. NRC used a synthesis procedure that they had previously developed in-house that exercises greater control over such wave parameters as groupiness factors and maximum wave height. A typical result of this procedure is shown in Fig. 3.

During the time of the hydraulic modelling of chainlocker flooding, the aerodynamic tests and the wave climate analysis and synthesis, work on the 1:40 scale hydrodynamic models proceeded. The design and construction of the model at NHL was undertaken by the staff of the Ship and Ocean Laboratory. The NHL model had pontoons fabricated from watertight plywood 16 layers thick, covered on both sides with a layer of epoxy and fiberglass matt. The construction of the pontoons is shown in Fig. 4. All vertical columns were constructed of aluminum sheet welded into tubes (Fig. 5). Tubes of rolled aluminum and reinforced plastic were used for the horizontal braces and the vertical trusses. The decks were made of watertight plywood and except for the centre area the entire deck section was watertight, but could be opened for water flooding.

The anchor bolsters were made of brass tubes and the stability cones were made of brass plates. The same material was used for the derrick, which was mounted with magnets. The three cranes were made of aluminum, the propeller ducts were made of PVC plastic and the boat bumpers were made of dyvinicell plastic. The helicopter deck, with the accommodation quarters, the winch control houses, the drill floor and pilot house were all modelled according to the general arrangement. The two forward columns had three winches each that were modelled.

The pontoons were subdivided into tanks according to the tank capacity plan of the rig and were filled with a salt-water solution to compensate for the slighter smaller tank volumes of the model than the prototype. A vented ballast system was installed, consisting of a longitudinal brass pipe at the center of each pontoon with cross-connections to 10 tanks on the starboard side and to 5 tanks on the port side. During the dive survey, manual control rods had been found to have been inserted in solenoid valves corresponding to these tanks.[1] The cross-connections to the tanks were opened or closed from the underside of the pontoons by a diver. This procedure was followed in a number of subsequent tests to simulate a specific ballast water transfer.

The chain lockers were modelled on the basis of the previous NRC chain locker flooding tests. All pipes going down to the chain lockers from the upper level were modelled as one tank at the centre of each corner column with a dyvinicell lining of varying diameter. The chain lockers were divided in three by wash bulkheads and were vented to the upper deck.

The deck was constructed of watertight plywood and was subdivided according to the principal accommodation arrangements. The watertight deck-volume was constructed to be flooded through small openings in all internal bulkheads and from the outside through openings in the accommodation quarter down through a stairwell opening in the upper deck.

The vertical centre of gravity was adjusted by rearranging lead weights in the four centre columns, (see Fig. 6). A pendulum method was used to determine the radii of gyration of the lightship and to adjust it to the specified values by moving onboard weights. All five loading conditions were achieved by filling the tanks in the pontoons.

Onboard instrumentation included light emitting diodes mounted on the ends of two booms attached to the derrick and at the foot of the derrick. These diodes were tracked by two horizontal and one vertical onshore cameras. The optical positioning system (OPTOPOS) based on these components provided motion measurement for six degrees of freedom. Three linear accelerometers were mounted inside the machine house to measure surge, sway and heave motion. Twelve force transducers were mounted at the fairleaders to measure the vertical and horizontal components of mooring line tensions. Two twin wire resistance wave probes were attached to the bow of the model to measure freeboard, and flooding of the forward chainlockers was measured by pressure cells mounted on the bottom of each chainlocker.

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[1] Of the 18 manual control rods recovered, 3 were inserted in solenoid valves associated with the drill water system and, consequently, did not affect the ballast system.

The NRC 1:40 scale hydrodynamic model was designed by the staff of the Arctic Vessel and Marine Research Institute (AVMRI) who also supervised its construction. The model was constructed completely in aluminum by the Manufacturing Technology Centre. The chainlockers in the four corner columns were included in the hydrodynamic model and the navel pipes were constructed such that the flow rate of water through them into the chainlockers was modelled correctly. Each pontoon was subdivided into sixteen tanks and piping was installed between ballast tanks (5 on the port and 10 on the starboard side) with remotely controlled pneumatic valves to initiate subsequent ballast transfer tests.

The vertical centre of gravity as well as the longitudinal and transverse radii of gyration were determined using standard inclining and swinging tests respectively, on a specially designed frame (Fig. 7).

The free floating longitudinal metacentric height (GM_L) and transverse metacentric height (GM_T) was checked by inclining the model in the water. Metacentric heights were also measured with all the mooring lines pretensioned to prototype values 235,000 lb.(1,045 kN). These larger values of GM are not to be confused with the smaller values of GM with "mooring pulldown" as used by ODECO. Natural periods of oscillation of the model were also measured.

A general layout of the hydrodynamic model showing the locations of onboard instrumentation is shown in Fig. 8. Each of the twelve mooring lines passed over a fairleader pulley, A1 to A12, which incorporated a load cell to measure the angles of the mooring lines to the model. Load cells, F1 to F12, measured the tension in each mooring line. Four capacitance wire wave probes were installed in perforated tubes in the chainlockers to measure volumes of water in the chainlockers and navel pipes. A reference accelerometer was mounted inside the drill house to measure heave acceleration. Eight light emitting diodes were mounted on a frame on the deck of the model. These diodes were monitored by two cameras that formed part of the Selspot system (similar to the NHL OPTOPOS System) used to measure six degrees of freedom motion response of the model.

The tests of the NHL model were carried out in the Ocean Basin shown in Fig. 9. The dimensions of the basin were 263 ft. x 164 ft. (80 m x 50 m) with a maximum depth of 33 ft. (10 m). Long crested waves are generated by a hydraulically operated, double flap type wave maker along the 164 ft. side. A second system of wave makers, along the 263 ft. side, consists of 144 individually-controlled elements. Each element is an electro-mechanically driven single flap unit. This system of wave generators has been designed primarily for generating short-crested waves.

The general test set-up is shown in Fig. 10. Wind was generated by four fans located as shown in the figure. In general, waves were generated by the wave maker (BM 2), but the multiflap machine (BM 3) was used for three tests. A photograph of the basin and model is shown in Fig. 11.

The test basin at NRC had dimensions of 164 ft. by 98 ft. by approximately 10 ft. (50 m x 30 m x 3 m). A water depth of 6.4 ft. (1.95 m) was used to simulate the water depth at the Ocean Ranger site of 256 ft. (78 m) at a scale of 1:40. Figures 12 and 13 show the general arrangement of basin and model. Three computer controlled high speed DC servo motors mounted on the wall of the basin were connected to the model by braided nylon filaments. These motors acted to produce resultant fluctuating forces and moments on the model, equivalent to the required wind loading.

For both wave directions (240° and 280°) used in the program, it was necessary to truncate ten of the twelve mooring lines at the walls of the test basin. At each truncation point, the mooring line passed over a fixed pulley, vertically to a spring which simulated the elasticity of the lines and then to a reel to permit the adjustment of pretension in the line. A static analysis of both the full-scale and the model mooring systems was carried out at NHL, using the ANKAN program, for the mooring systems at both the NHL and NRC basins. The physical tests were conducted by measuring the forces required to move the moored model in the surge and sway directions.

The overall test objectives for both basins included various phases either known or potentially applicable to the situation of the *Ocean Ranger* during the period from approximately 2200Z (1830 NDT) on the 14 February 1982 to 0800Z (0430 NDT) on the morning of February 15th., (171 tests in all).

The first objective was to investigate the behaviour of the unit, hung-off, from 2200Z. The envelope of tested parameter variance, for 81 tests, was: Draft of 79 ft.; free floating GM_L of 8.86 ft. to -0.54 ft.; initial trim from 0° (level) to +8° (by bow); fully pretensioned moorings or ones with leeward lines slackened; wind direcion of 280° True; time period from 2200Z – 0918Z (tests of varying duration of 1 to 10 hours). In some tests a transient wave(s) of approximately 90 ft. height was run.

During the July 1982 dive survey soundings of No. 10 tanks indicated the possibility of a deballasting operation. This second objective used the following envelope of tested parameters for 13 tests: Draft of 72 ft.; free floating GM_L of 5.82 ft. or 2.54 ft.; initial trim of 0° (level) to +4° (by bow); fully pretensioned moorings or ones with leeward lines slackened; wave direction 240° True; wind direction 280° True; time period 2300Z to 2400Z or 0500Z to 0600Z.

The third objective was to simulate a hypothetical inadvertent transfer of ballast that would have led to the as sounded lower hull tank contents. The envelope of test parameter variance for 30 tests was: Draft of 93 ft.; free floating GM_L of 8.11 ft.; initial trim of -4° (by stern) to +12° (by bow); fully tensioned moorings or ones with leeward lines slackened; wind direction of 280° True; wave direction of 240° True or 280° True; time period from 2300Z to 2400Z or 0500Z to 0600Z with transient waves injected into some tests.

The fourth objective was to simulate a hypothetical inadvertent transfer of ballast leading to "minimum contents" of lower hull tanks based on possible errors in the dive survey tank soundings. The parameter variance in the sequence of 5 tests was: Draft of 86 ft.; free floating GM_L of 6.51 ft.; wind direction of 280° True and wave direction of 240° True.

The fifth objective examined a free transfer of water ballast in lower hull tanks whose solenoid valves were found with manual control rods inserted. A total of 15 tests were conducted with drafts of either 72 ft., 79 ft., 86 ft., or 93 ft.; free floating GM_L of 4.64 ft. to 8.11 ft.; initial trims of -4° (by stern) to 0° (level); fully tensioned moorings; wind direction of 280° True; wave direction of 240° True; time period from 0500Z to 0700Z (in one hour tests).

A single test of simulated impact of the rig's pontoons with the seabed was carried out. The starting conditions for the test (deckhouse and chain lockers flooded) corresponded to the final conditions of the previous 93 ft. draft tests in Objective 5. The tests specified a free floating GM_L of 8.11 ft., ballast valves open; wind and waves from 280° True and additional transient waves.

A final set of model tests were performed within the framework of conditions thought to have had some possible bearing on the loss. The first six tests were carried out a draft of 72 ft.; with a free floating GM_L of 5.82 ft.; with moorings allowed to drag; with ballast pipes and deckhouse open; with no wind; with waves from 280° True; with test times from 0500Z to 0700Z (in one hour intervals). This series of tests included two important tests in which the entire lower deck was allowed to flood as were the two forward columns. It was these tests that produced the only capsizes of the model.

Three tests were conducted at a draft of 79 ft. and a free floating GM_L of 0.96 ft. with an initial trim of 0°, with ballast valves and deckhouse closed and with no wind. These tests used a JONSWAP Spectrum, one with short crested waves, one with long crested waves and one with a cross sea of regular long crested waves. Four tests were also carried out at this draft with a reference of GM_L of 1.36 ft. to 4.64 ft. with no wind and with waves from 240° True from 2300Z to 2400Z or from 0600Z to 0700Z. Two tests at a free floating GM_L of 4.64 ft. and a draft of 79 ft. were conducted. The moorings were allowed to drag, there was no wind, and the ballast pipes, deckhouse, lower deck and forward columns were open. These tests were analogous to the two tests conducted at a draft of 72 ft. but were both carried out with a test time of 0500Z to 0700Z.

A series of four tests were also conducted at 79ft. draft with a reference GM_L of 2.86 ft. or 4.64 ft. with wind only (from 280° True) from a test time of 2200Z to 2300Z.

A group of seven tests were carried out to investigate the phenomenon of wave induced tilt. A draft of 79 ft. was used, for three tests, with a free floating GM_L of 0.30 ft., waves from 240° and no wind. Regular waves or a JONSWAP spectrum were utilized. The remaining four tests were carried out at a draft of 72 ft. with a free floating GM_L of 1.0 or 1.76 ft. at similar test conditions.

Part 2 objectives of the model test program included a series of eighteen tests that investigated the behaviour of the rig at conditions other than those that were thought to be applicable to the loss.

A series of four tests were conducted with a draft of 58 ft., free floating GM_L of 1.87 ft., fully tensioned or slack mooring, wind and waves from 280° True with a test time of 2300Z to 2400Z. A single test was conducted with a 64 ft. draft, a free floating GM_L of 4.92 ft. and fully tensioned moorings, wind from 280° True, waves from 240° True and a test time of 0500Z to 0600Z.

Five tests employed all-chain moorings at a draft of 80.8 ft. or 65.3 ft. with a free floating GM_L of 4.92 ft. to -0.54 ft., wind from 280° True and waves from 240° True with a test time of 0500Z to 0600Z.

The final eight tests were the only ones carried out at a water depth of other than 255 ft., namely 400ft. The draft was 79 ft. with a free floating GM_L of 4.64 ft. or 1.36 ft., trim was from either 0° (level), +4° (by bow) or -4° (by stern). The waves were from 240° True and wind was from 280° True, test times were 2200 to 0342Z or 03V37Z to 0918Z or 0500Z to 0600Z. Moorings of wire/chain were pretensioned or slack (for one test).

These latter sets of tests were carried out in collaboration with the Mobile Platform Stability (MOPS) research project funded by the Norwegian Maritime Directorate (NMD), the Norwegian Offshore Association (NOF) and the U.K. Department of Energy (DOE).

Under the normal conditions that applied to the *Ocean Ranger* on February 14, 1982, that is, corresponding to a moored draft of 79 ft. and a free floating GM_L of 4.64 ft., the response or motions of the hydrodynamic model did not indicate any stability problems. However, in such storm conditions it would have been advisable for the rig to deballast to a survival draft, in order to avoid damage to the deck structures, or to prevent flooding of the chain lockers by waves of extreme height.

The rig did not appear susceptible to downflooding at either 79 ft. or 86 ft. draft unless it was subject to large transient waves or had an initial trim of more than 10° by the bow. This last condition was only true with slack moorings and with the lowest metacentric height of the test series.

At a draft of 93 ft. the incidence of chain locker flooding increased markedly. The tests indicated that there was some water on the deck at a bow trim of 4°. However, significant flooding occurred at approximately 8° of bow trim with slack mooring and at approximately 12° of bow trim with fully tensioned moorings. Once waves began to spill on the deck of the hydrodynamic model, the chain lockers filled with water extremely rapidly because of the large navel pipe openings and also because the rate of flooding increased with increasing forward trim. Once the chain lockers began to flood, it was unavoidable that they would eventually flood completely.

The tests conducted at drafts 72 ft., 79 ft and 93 ft. allowing the free flow of ballast water between tanks, found to have solenoid valves containing manual control rods, resulted in dangerous trims by the bow. Bow trims exceeded 15° and resulted in progressive and critical flooding of the bow chain lockers.

The hydrodynamic model capsized by the bow during a test for which the moored draft was 72 ft. and the free floating GM_L was 5.82 ft. However, it was necessary for the ballast valves to be open and the chain lockers, deck spaces and forward columns to be flooded. Similar tests from a draft of 79 ft. and with free floating GM_L of 4.64 ft. resulted in the model sinking to a final position with the pontoons resting on the bottom at an angle of approximately 56°.

A bottom impact test was conducted to determine if the hydrodynamic model would capsize from an initial moored draft of 93 ft. and a free floating GM_L of 8.11 ft. The test simulated the flow of ballast in the pontoons and the flooding of the bow chain lockers and deck spaces as well as the port trim tank (PT-I). Transient waves with heights of up to 90 ft. were simulated to see if the model would capsize. During the test, the model rested heavily on the bottom at a pitch angle of approximately 52°, and it was apparent that it would have been unlikely for the *Ocean Ranger* to have capsized from this draft.

The wave induced tilt test showed that the hydrodynamic model at a moored draft of 72 ft. and a very low metacentric height acquired steady angles of tilt even in irregular waves.

Tests at the survival draft of 58 ft. with a free floating GM_L of 1.87 ft. showed a reduced stability, due to the location of the stability cones, for bow trim angles greater than approximately 1°. The motions of the hydrodynamic model during the irregular wave test were erratic, and steady trim angles by the bow up to a maximum of 4° were measured.

It was concluded by the Royal Commission's Chief Technical Advisor that capsize of the rig was possible at all drafts up to and including 82-83 ft., but not possible at a draft of 93 ft. The analysis referred to a time dependency whereby, in the 79 ft. test, the model continued to flood in the 'tween deck before a large wave created capsize conditions. Alternatively, once the rig attains a possible capsize condition, a suitable large wave permitting capsize must occur before additional flooding of the 'tween deck increases the displacement such that capsize is prevented.

The model test program provided insight into the general motion response of the rig at a number of drafts and clearly demonstrated the importance of the mooring system in shallow water. Significant response was observed at rig-natural frequency in addition to that at wave frequency for a number of different values of GM. The downflooding angles were investigated at a number of drafts and were found to be less than what was predicted by the USCG study. In general, the model tests clearly established that at level trim the *Ocean Ranger* had quite favourable motion response. However, prior to this set of tests the behaviour of semisubmersible rigs at various trims or in a damaged condition has not received exhaustive attention. The data obtained in the present series of tests should give further understanding in this important area.

Technical advances in model testing techniques included model construction, simulation of realistic wave and wind fields, modelling of ballast transfer and free surface effects, modelling of chain locker flooding and modelling of mooring systems and of second order wave effects. The test basins at NHL and NRC successfully completed a very sophisticated and exhaustive test program whose data should provide a basis for subsequent further analyses. Such analyses should complement existing understanding of semisubmersible behaviour.

FIGURE 1 Hydraulic actuator – controlled frame for immersing 1:15 and 1:40 model decks – NRC

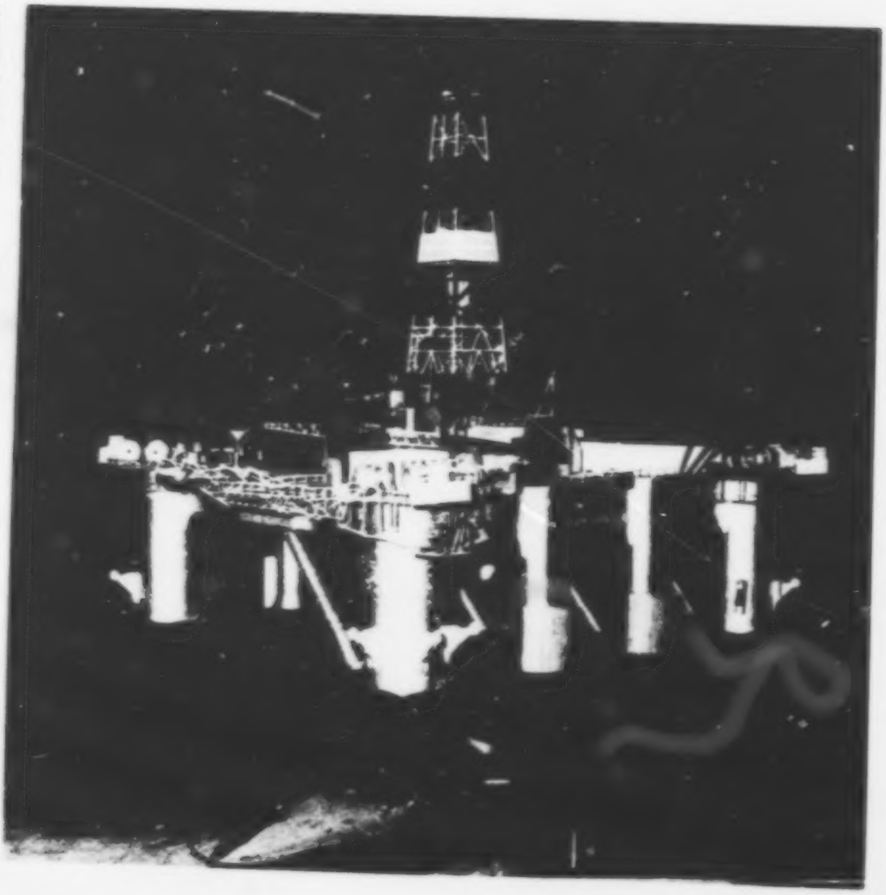
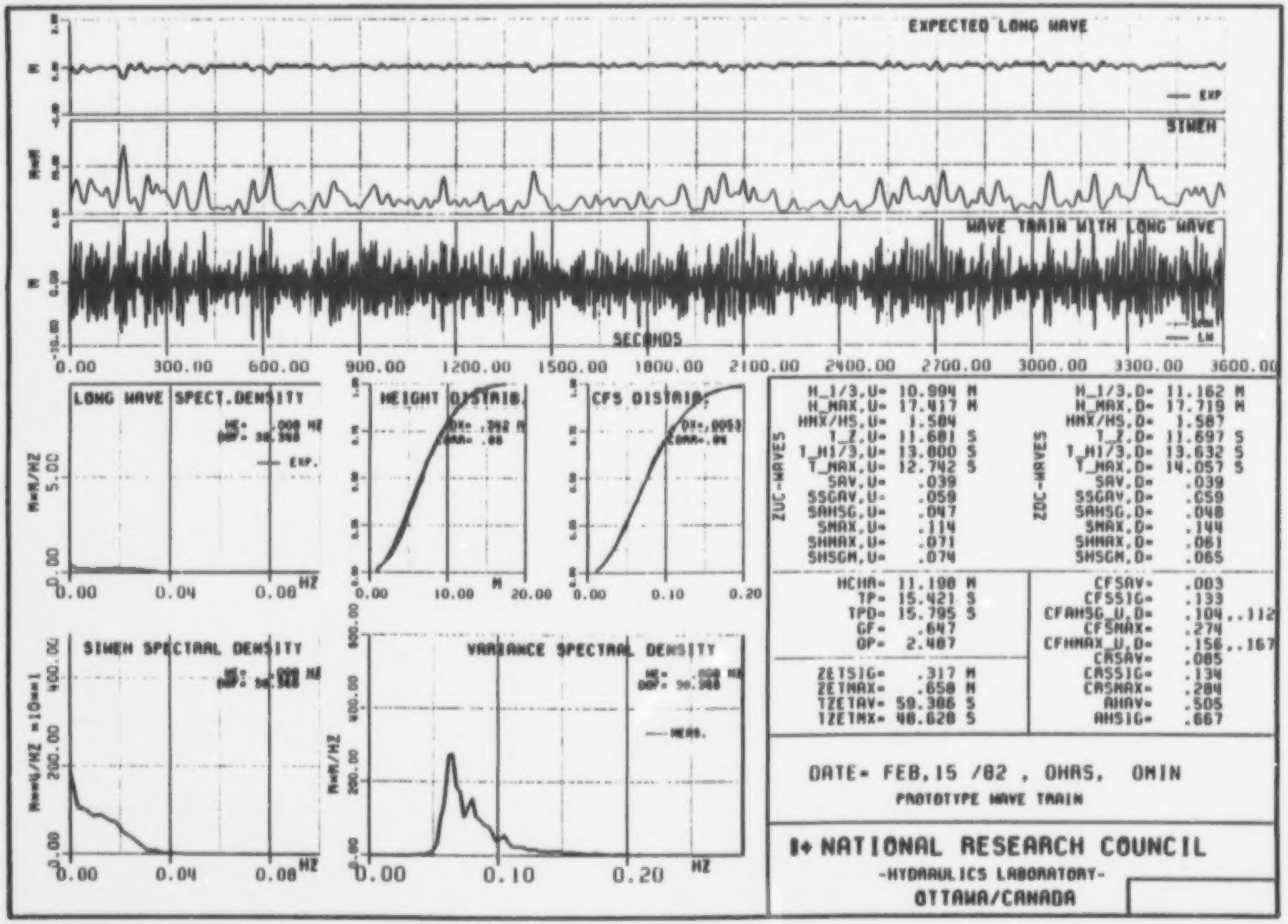


FIGURE 2 View of model showing the deck and column detail – NAE



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ZUC-WAVES
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     H_MAX,U= 17.417 M
    HMX/HS,U=  1.584
       T_Z,U= 11.681 S
    T_H1/3,U= 13.000 S
     T_MAX,U= 12.742 S
       SAV,U=   .039
     SSGAV,U=   .059
     SAHSG,U=   .047
      SMAX,U=   .114
     SHMAX,U=   .071
     SHSGM,U=   .074

ZDC-WAVES
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     H_MAX,D= 17.719 M
    HMX/HS,D=  1.587
       T_Z,D= 11.697 S
    T_H1/3,D= 13.632 S
     T_MAX,D= 14.057 S
       SAV,D=   .039
     SSGAV,D=   .059
     SAHSG,D=   .048
      SMAX,D=   .144
     SHMAX,D=   .061
     SHSGM,D=   .065

        HCHA= 11.198 M
          TP= 15.421 S
         TPD= 15.795 S
          GF=   .647
          QP=  2.487

      ZETSIG=   .317 M
      ZETMAX=   .658 M
     TZETAV= 59.386 S
     TZETMX= 48.628 S

       CFSAV=   .003
      CFSSIG=   .133
 CFAHSG_U,D=   .104..112
      CFSMAX=   .274
 CFHMAX_U,D=   .156..167
       CASAV=   .085
      CASSIG=   .134
      CASMAX=   .284
        AHAV=   .505
       AHSIG=   .667
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DATE= FEB,15 /82 , 0HRS, 0MIN

PROTOTYPE WAVE TRAIN

NATIONAL RESEARCH COUNCIL
-HYDRAULICS LABORATORY-
OTTAWA/CANADA

FIGURE 3 Prototype wave train – NRC

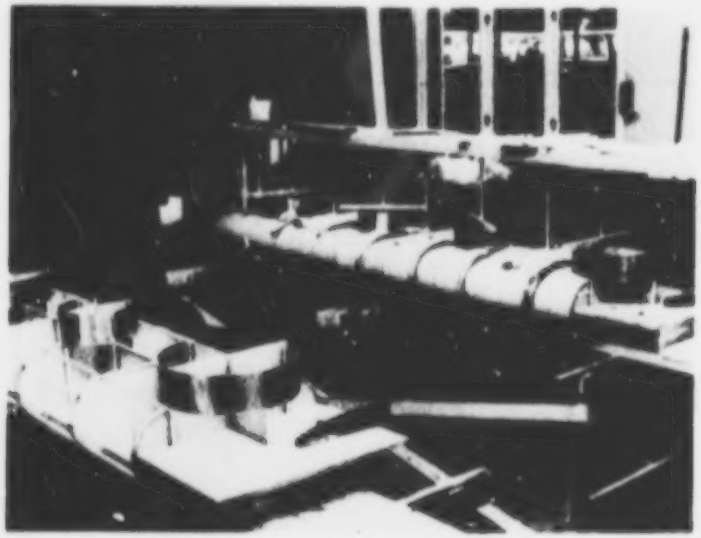


FIGURE 4 Construction of the pontoons – NHL

FIGURE 5 Model assembly – NHL

FIGURE 6 Adjusting arrangement for center of gravity – NHL

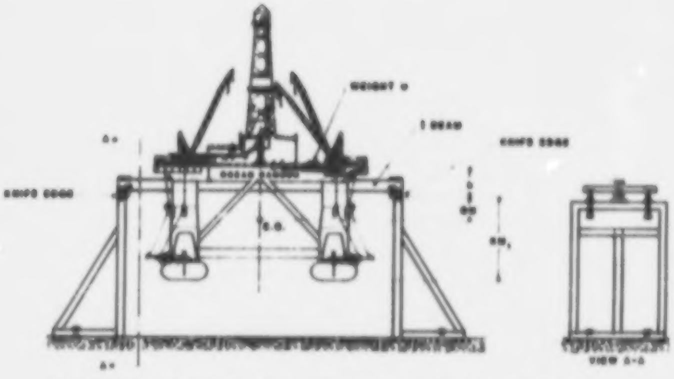

WEIGHT W
I BEAM
KNIFE EDGE
KNIFE EDGE
VIEW A-A

FIGURE 7 Frame for hydrodynamic model inclining tests – NRC

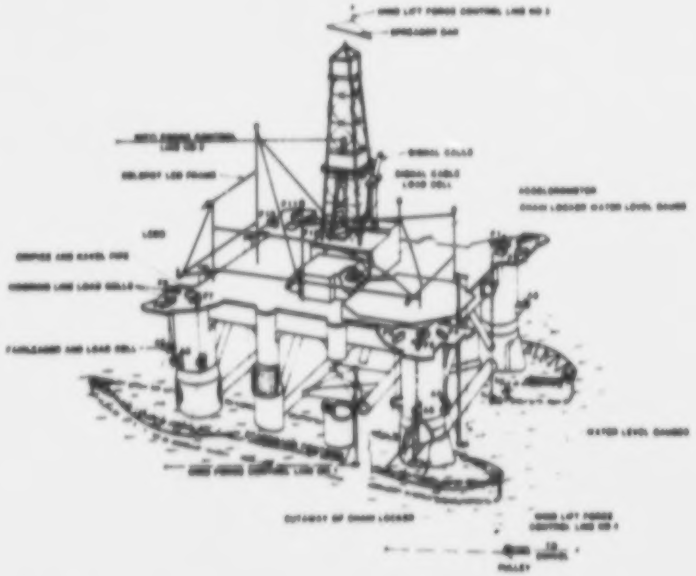


FIGURE 8 Instrumentation on-board the hydrodynamic model – NRC

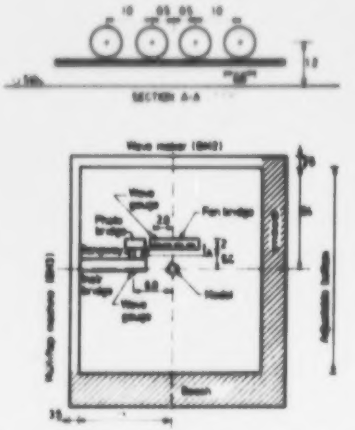

10
0.5
0.5
10
SECTION A-A
Wave gauge
Fan bridge
Photo bridge
2.0
9.0
Model
Wave gauge
Beach

FIGURE 10 General test set-up – NHL

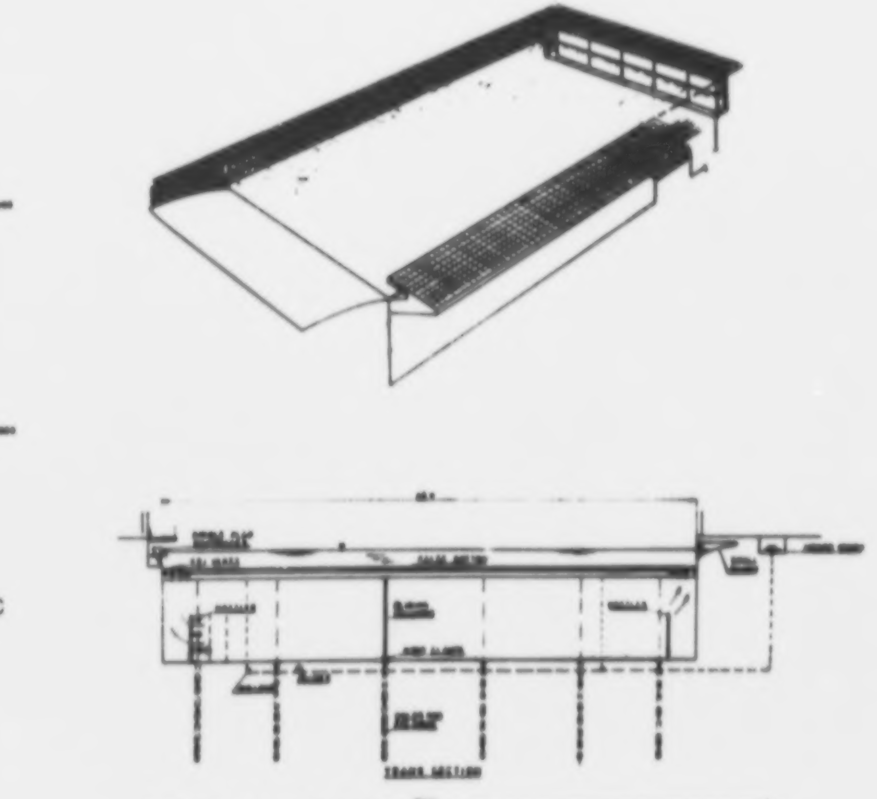


FIGURE 9 Design of the ocean basin – NHL

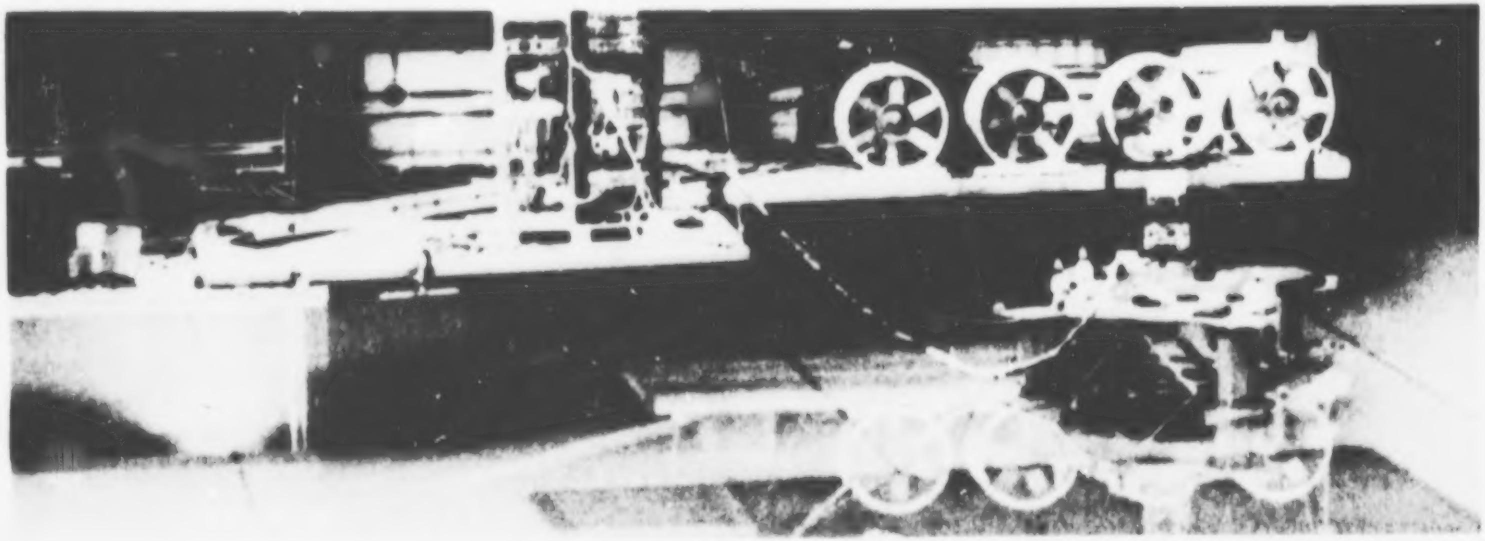


FIGURE 11 General test set-up – NHL

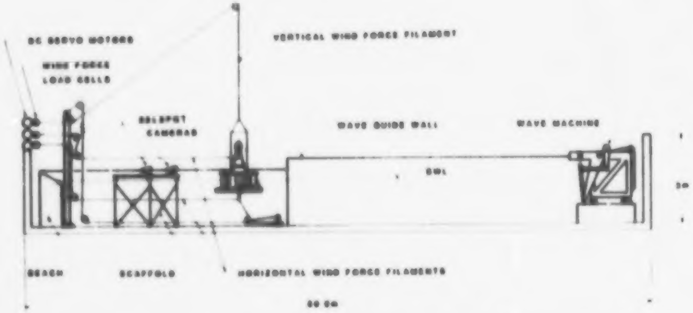

DC SERVO MOTORS
WIND FORCE
LOAD CELLS
SELSPOT
CAMERAS
VERTICAL WIND FORCE FILAMENT
WAVE GUIDE WALL
WAVE MACHINE
SWL
3m
BEACH
SCAFFOLD
HORIZONTAL WIND FORCE FILAMENTS

FIGURE 12 Schematic elevation view of the test basin – NRC

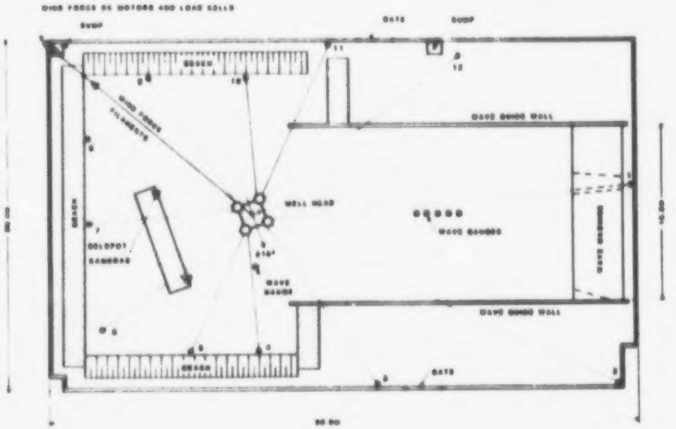

WIND FORCE DC MOTORS AND LOAD CELLS
SUMP
GATE
SUMP
BEACH
WIND FORCE
FILAMENTS
WAVE GUIDE WALL
WELL HEAD
WAVE GAUGES
SELSPOT
CAMERAS
WAVE
GAUGE
WAVE GUIDE WALL
BEACH
GATE

FIGURE 13 Mooring arrangement in the test basin for waves from 240° and wind from 280° – NRC

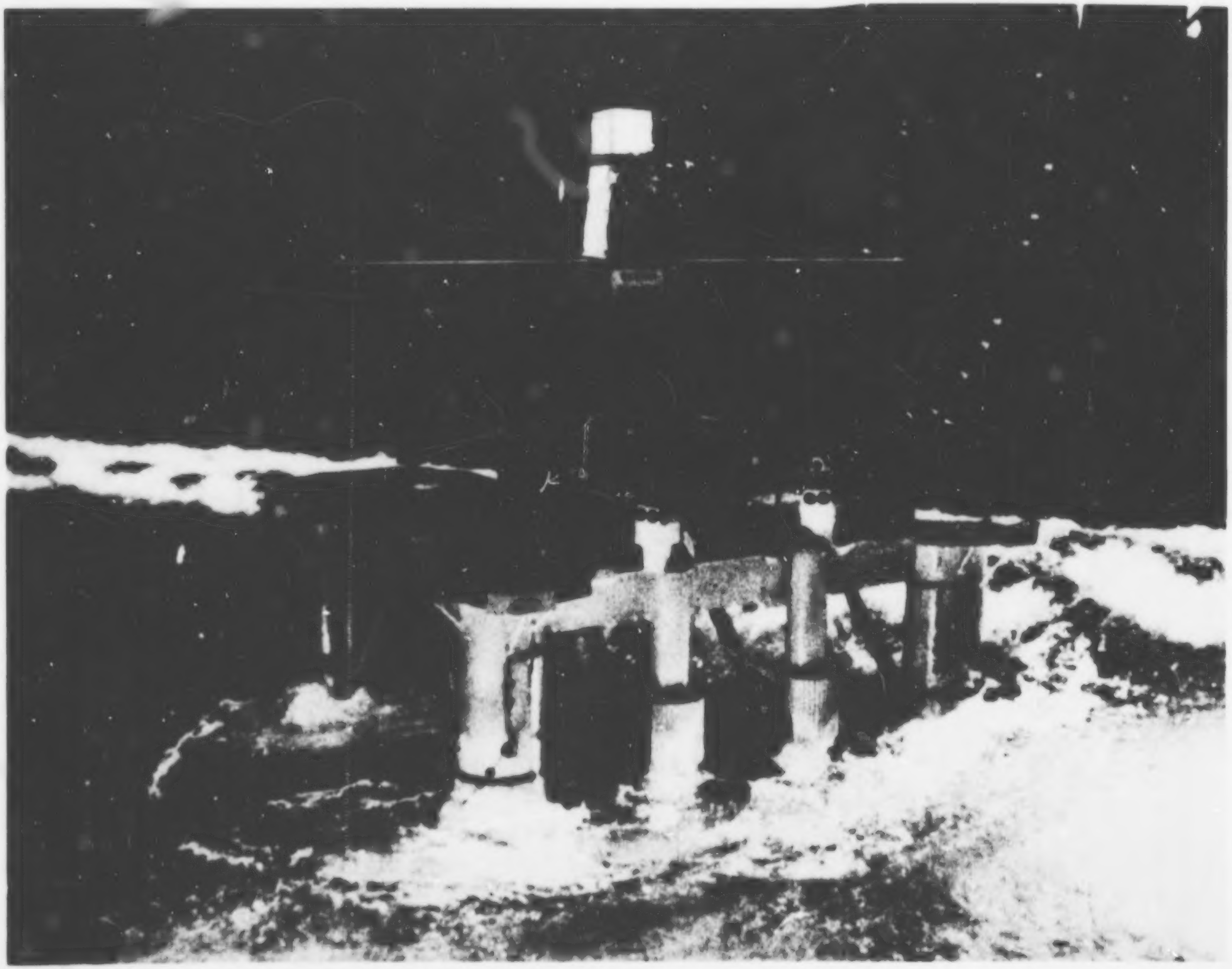


FIGURE 14 The *Ocean Ranger* hydrodynamic model in the NHL test basin

Item F-6
Analysis of Lifesaving Equipment Performance

R.L. MARKLE, Acting Chief,
Survival Systems Branch
Merchant Vessel Inspection Division
Office of Merchant Marine Safety
U.S. Coast Guard

INTRODUCTION

The Mobile Offshore Drilling Unit *Ocean Ranger* sank in the early morning hours of 15 February 1982 in the Atlantic Ocean about 175 nautical miles east of St. John's, Newfoundland. All 84 persons aboard are presumed to have died as a result of the casualty; 22 bodies were recovered. The major contributing cause of death for all 22 was identified as hypothermia (loss of body heat, in this case due to immersion in cold water). The prevailing water temperature at the time of the casualty was approximately 31°F (-0.7°C). As a result of this casualty, both the U.S. Coast Guard Marine Board of Investigation and the National Transportation Safety Board have recommended that exposure suits be provided for all persons on board such units that operate in waters where hypothermia is a severe hazard.

The *Ocean Ranger* was built in Japan, initially for Panamanian registry. As such, the lifesaving equipment on board did not necessarily comply with U.S. Coast Guard requirements. In 1979, it was registered as a U.S. vessel, and at that time it would have been required to comply with U.S. Coast Guard requirements for lifesaving equipment (46 CFR 108.501 – 108.527, and Navigation and Vessel Inspection Circular (NVC) 3-78). For the *Ocean Ranger*, these regulations require totally enclosed lifeboats for 100% of the persons on board (100 persons), davit launched liferafts for 100% of the persons on board (or additional totally enclosed lifeboats for 100% of the persons on board), and life preservers for 125% of the persons on board. (A number of other items which were not factors in the survival aspects of the casualty are also required.) The Coast Guard Marine Inspection Office in Providence, RI issued a letter dated 18 December 1979 after the initial inspection for certification that required the *Ocean Ranger* to be equipped with the required U.S. Coast Guard approved totally enclosed lifeboats and davit launched liferafts prior to the next inspection for certification due December 1981 (reference 15 – references listed on page 363). At the time of the casualty, the lifesaving equipment included:

> 2 unapproved totally enclosed lifeboats installed in davits and operational – total capacity 100 persons;
>
> 1 U.S. Coast Guard approved totally enclosed lifeboat installed in davits and operational (this installation had not been inspected or accepted by the Coast Guard at the time of the casualty) – total capacity 58 persons;
>
> 1 U.S. Coast Guard approved totally enclosed lifeboat stowed on deck, not operational – total capacity 58 persons;
>
> 10 U.S. Coast Guard approved inflatable liferafts (not davit launched) – total capacity 200 persons;
>
> 127 life preservers labeled as U.S. Coast Guard approved (see section on LIFE PRESERVERS), equipped with lights and retroreflective material
>
> – U.S. Coast Guard approved work vests (quantity unknown).

In light of the failure of this equipment to save anyone on board the *Ocean Ranger*, the Marine Board of Investigation requested that this analysis of the performance of the equipment be prepared. This analysis was made through examination of exhibits and records of the Coast Guard Marine Board of Investigation, and through inspection and testing of the lifesaving equipment recovered from the *Ocean Ranger*.

LIFEBOATS

At the time the *Ocean Ranger* was constructed, it was equipped with two Harding totally enclosed lifeboats built by Björke Båtbyggeri (now Harding AS) of Rosendal, Norway. These boats were identical, 26 ft. long and had a rated capacity of 50 persons. This lifeboat design has a fibrous glass reinforced plastic (FRP) hull and cover made using methods and materials that are typical for this type of construction. Power is provided by a Sabb diesel engine capable of propelling the boat at a speed of approximately 6 knots. The boat is nominally self-righting, in that if capsized it returns to an upright position, provided that all persons inside are secured to their seats with the seat belts and that there is no significant accumulation of water inside the boat.

The release gear on the Harding boats was of the Mills type, allowing the boat to be disengaged only when the weight of the boat is not supported on the falls (off-load release). The purpose of this arrangement is to prevent the boat from being released before it is waterborne. A single handle located near the release gear support bar inside the boat at the aft end controls this release gear. Cables are attached to this handle which are connected to both the fore and aft release hooks. When the load of the boat is off of the hooks, pulling on the handle overcomes the force of the hook counterweights and opens the hooks simultaneously. When the load of the boat is on the release gear, the force required to open the hooks exceeds that which can be applied manually, so the release does not work in the on-load mode.

One of these boats (#1) was installed on the forward end of the *Ocean Ranger*, just to the port side of center. The other boat (#2) was installed on the aft end, also on the port side of center. In order to comply with the regulations requiring 200% capacity in a combination of lifeboats and davit launched liferafts, the owners of the *Ocean Ranger* contracted with Watercraft America to provide Coast Guard approved boats (reference 6). At the time of the casualty, one of these boats (#4) had been installed on the aft end of the unit, just to the starboard side of the centerline. The other boat (#3) was to have been installed on the forward end just to the starboard side of the centerline, but this installation had not been completed and this boat was stowed on the deck of the *Ocean Ranger* at the time of the casualty (reference 11c).

The Watercraft America lifeboats were built by Watercraft America, Inc. of Edgewater, Florida. These boats were identical, 28 ft. long and had a rated capacity of 58 persons. This lifeboat design is similar to the Harding in that FRP is used in construction of the hull and cover. Power is provided by a Westerbeke (marinized Perkins) diesel engine capable of propelling the boat at a speed of approximately 6 knots. The boat is nominally self-righting to the same degree as the Harding boat. The release gear in this boat is a Rottmer Gear which is an on-load release. On-load release gear allows the boat to be disengaged from the falls at any time, even with the weight of the boat on the falls.

In October 1981, the U.S. Coast Guard published NVC 10-81 on certification and inspection of certain categories of existing vessels, including foreign flag vessels brought under U.S. flag. This NVC contains a section on acceptance of existing lifeboats which were not built under Coast Guard approval and inspection. It lists the features which are regarded as critical to satisfactory lifeboat performance. If the lifeboats on an existing vessel comply with all of these critical requirements, the lifeboats can be used on the vessel as long as they remain in good and serviceable condition. Had this NVC existed at the time the *Ocean Ranger* was brought under U.S. registration and the lifeboats reviewed under its provisions, the following deficiencies would have been noted:

a. The release gear is of the Mills type (see preceding discussion). NVC 10-81 requires that the release gear be controlled from a single point, providing simultaneous release of the hooks while supporting the full weight of the boat (on-load release). The most common release gear of this type is the Rottmer mechanical disengaging apparatus, but recently other types of release gear have been approved that perform the same function. This type of release gear has been required on U.S. Coast Guard approved lifeboats for ocean-going vessels since the 1940s because it allows the boat to be released if the vessel is underway or stationary in a current, and it also allows a carefully timed release for rising and falling water in heavy seas. Retrofit of an on-load release for the Harding boats would have been a major modification.

b. Compared with similar Coast Guard approved boats, the rated capacity of the Harding boat appears to be slightly high at 50 persons. Application of NVC 3-79 (referenced in NVC 10-81) could possibly have resulted in a reduction in capacity of 1 to 3 persons.

c. Under NVC 10-81, the engine is required to start by hand or by a hand-energized system at 20°F without starting aids. Alternatively, engine starting depending on cold starting aids is permitted if the aids are of the permanently installed type and if starting can be accomplished at 5°F with aids and 40°F without aids. The Sabb engine is equipped with a hand crank starting system, but it is not known if it would function at 20°F without aids. If aids were necessary, the type provided on the engine would not be acceptable as a permanently installed type because two screw-in plugs on the side of the engine block must first be removed with a wrench, followed by injection of oil into the holes or insertion of a "cigarette" into the hole, and then replacement of the plugs. Testimony before the Marine Board indicated that on the *Ocean Ranger*, heat lamps were kept in the lifeboat engine boxes to facilitate cold starting, and that a can of ether was also kept available (reference 11g).

LIFEBOAT #1

When lifeboat #1 was first sighted and recovered the day after the casualty, it was flooded, right side up, and down by the stern. There was a large hole in the bow where the forward release gear support cut through the hull and was torn out, and there was a hole in the cover in the area where the rear hatch and helmsman's tower should be. No one was inside the boat when it was recovered and there were no signs of bodies or lifejackets in the vicinity (references 11d, 11h). Only 8 of the required 12 hand flares were found in this boat, but testimony indicates that the flares sighted by the standby boats were probably from boat #2 (references 11g, 12).

In the process of recovering the boat with cables, the boat suffered additional damage. This is apparently when the cover was crushed and the hull damaged in a number of places (reference 11d). In addition to the damage caused by the release gear, there were two other areas of damage that apparently did not occur during recovery. These are two "L" shaped inward fractures on either side of the hull several feet aft of the bow. These fractures match the position of the davit chocks on the launching platform and indicate that the launching sequence for this boat may not have begun, or had just begun when it was separated from the launching platform. The boat and its release gear arrangement are shown in Figure 1.

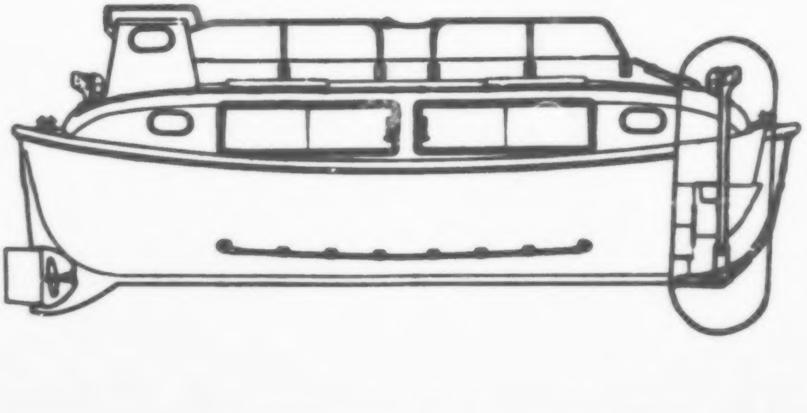


FIGURE 1 Harding 26 ft. totally enclosed lifeboat. Internal view at forward end shows release gear arrangement. The hook is attached to a support bar which is in turn attached to the keel shoe by a pin joint. The keel shoe is "glassed in" at the keel and is the means of transferring the load of the boat to the release gear. The support bar is held vertically by a flange bolted to the fiberglass at the point where the support bar penetrates the cover.

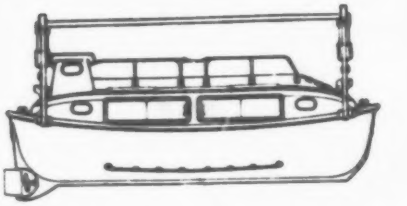


FIGURE 2A Harding lifeboat #1 shown in normal stowage position in davit.

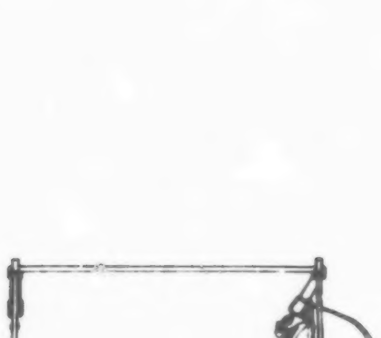


FIGURE 2B Aft release hook has been opened, allowing aft end of boat to fall. Davit chocks at forward end normally in contact with gunwale dig into hull, leaving "L" shaped inward fractures on both sides of the hull.

Figures 2a through 2d depict a series of events which could account for the damage sustained by this boat. Note that there were no surviving witnesses to the release of this boat or any of the other boats, and consequently no testimony to support this scenario. It is deduced from the damage found during the post-casualty inspection of the boat, and in the opinion of the author represents the most probable series of events. The following is a description of the events depicted in Figures 2a through 2d:

a. Boat #1 was at the port bow, the area of the *Ocean Ranger* which is believed to have been the first area of the main deck to enter the water. Seas were heavy at the time, so as the launching platform with the boat approached the water, it would have been struck by a series of waves. The waves were such that the boat would have been subject to severe forces as is evident by the distortion and damage in the aft release hook supporting structure and surrounding FRP laminate. The waves would have lifted and dropped the boat repeatedly, and when the boat was supported by a wave the load would be off the release hook and it could be easily moved to the open position by overcoming the force of the counterweight on the hook. This apparently happened to the aft hook while the boat was being battered by the waves resulting in release of the aft hook. The damage to the rear helmsman's tower and hatch could have occurred at this point since the aft release gear is adjacent to this area.

b. Supported only by the forward hook, the davit chocks on the launching platform lost contact with the gunwale and dug into the hull below and behind their normal position, as the boat was wedged between the chocks on either side. This caused the "L" shaped fractures discussed above. Had the launching sequence been started, the davit chocks would not have contacted the hull in this manner.

c. Hanging vertically from the forward hook, and possibly aided by leverage on the hull by the davit chocks as well as continued battering by the waves, the forward release gear structure began to slice through the bow.

d. Finally, the support shoe was torn out of its keel connection. This allowed the boat to separate completely from the unit and float away. Damage to the helmsman's tower could also have occurred at this point since the boat dropped stern first.

In this damaged condition, the boat would have been open to the sea and flooded, and would have been stable floating either right side up or capsized due to the arrangement of the foam filled flotation compartments along either side of the hull. Because of the immediate flooding of the boat as soon as it fell from the launching platform and entered the water, it would have been very difficult for anyone inside to start the engine or keep the engine running and get underway.

In addition to the damage, another item that suggests that launching preparations had not been completed is the battery charger. This was connected to power aboard the rig by a conventional extension cord. The cord was apparently led out through one of the hatches and the hatch closed over the cord. The charger was found in the boat still plugged into the extension cord, and the extension cord was severed at approximately the place where it would have been led through the closed hatch. Apparently the closed hatch severed the cord as the boat separated from the launching platform. There was no trace of a heat lamp in the engine box or its electrical supply, however.

A telex from the *Ocean Ranger* to CDECO on 11 January 1982 indicated that there was a problem with the lowering control wire on boat #1 chafing on an obstruction. This is the wire that leads inside the boat which must be pulled and held to cause the boat to lower. The telex stated that a modification to rectify the problem could be carried out aboard, but there was no subsequent verification that this modification was completed, and there was no discussion about how or if this interfered with the lowering of the boat (reference 5). There was no discussion found in testimony as to whether or not this was a problem.

The seat belts in the boat would have been useless in their primary role as part of the re-righting system since the boat was flooded, however, the seat belts could have lessened injury during the time the boat was separating from the launching platform. One seat belt mounting plate in this boat has been bent inward, and the FRP structure that secures the stud for the mounting shows evidence of distress from this inward pull. This seat is near the engine box and the boat operator's position where one of the first few persons aboard the boat might sit. There is, however, no way to determine if this damage to the seat belt mounting

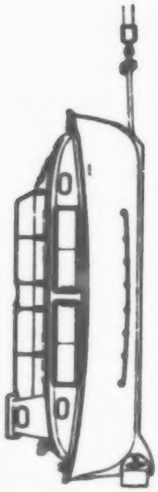


FIGURE 2C (Davit omitted for clarity.) Release support bar connection to cover is intended to stabilize the support bar in the vertical position in normal circumstances. It is unable to support the boat hanging from one end, so it pivots on the pin connecting it to the keel shoe, ripping out the stem area of the hull as it goes.

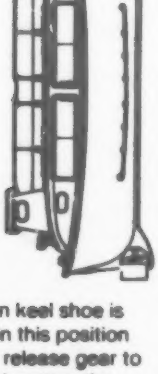


FIGURE 2D The glassed-in keel shoe is unable to support the boat in this position and is torn out, allowing the release gear to separate from the boat which enters the water stern first.

occurred during the abandonment of the *Ocean Ranger*.

The seat belt and mounting designs appear to have shortcomings. The buckles are of a conventional aircraft design with a lift latch buckle that appears to operate easily. This attaches to the other belt-half that includes a sliding adjuster. This adjuster belt does not have a tab at the end, and the adjuster can easily be slipped off the end of the belt by holding the belt and shaking it. It was also noted that it is easy to replace the adjuster mechanism on the belt incorrectly, and if this is done, the adjuster will slide off the belt easily as well. Many of the belt adjusters were found in the boat separated from the belts. Other than simply falling off the belts, another possible explanation for the separation of so many belt adjusters could be that the adjusters were not adequate for holding the passengers in place. There are no known standards that apply to lifeboat seat belts, but there are standards that apply to automotive seat belt assembly strength. In order to determine the suitability of the adjuster mechanism, three belt sets were removed from the boat and sent to United States Testing Laboratory to be subjected to the belt assembly test from Federal Motor Vehicle Safety Standard (FMVSS) 209 of the National Highway Traffic Safety Administration (NHTSA). This involves application of a 5000 lb. load to a loop formed by the belt. One of the seat belt sets passed the test, and the other two failed in the stitching, but not in the adjuster mechanism (reference 17). Since there was no evidence of stitching failure in any of the belts that were examined in the boat, it is probable that the belt adjusters did not fail under load.

The seat belt mounting arrangements on the thwarts appear to be inadequate. These are simply studs threaded into a blind hole in the FRP thwart structure and a backing plate which appears to be about 1/8 in. to 3/16 in. thick, so that only two or three stud threads would be engaged in the backing plate. The FRP would have little value in holding the stud threads. The studs had been torn out of a number of these holes and the threads were stripped. One thwart recovered from boat #2 showed similar damage to these mountings, and one of the stripped holes had been drilled all the way through to the inside of locker underneath the thwart and a bolt used to replace the stud. This indicates that these mountings were a problem before the casualty, and that it can not be concluded that all of these mountings failed in the course of the casualty.

In summary, there is no physical evidence sufficient to draw a conclusion as to whether or not boat #1 was ever occupied.

LIFEBOAT #2

Boat #2 was first sighted underway. It came alongside the *Seaforth Highlander* and capsized slowly as four to five men scrambled out of the boat. Between four and nine men were seen shortly after clinging to the overturned boat. None of these persons were able to be recovered because of the heavy seas and their inability to assist in their own rescue (references 11b, 12). In a later recovery attempt, seven bodies floated out through the hole in the bow and approximately 20 more bodies were seen through an open hatch still belted to their seats. It is known that this was the same boat because the *Seaforth Highlander* ring buoy that had been secured to the boat just before it capsized was still attached (reference 11e). This boat was therefore launched with approximately 31 people or more aboard.

The slow capsizing suggests that the boat was partially swamped as does the testimony indicating that the boat was being bailed as it approached (references 11b, 12). The shift of the weight of the persons leaving the boat on one side was apparently enough to capsize the boat which had diminished stability due to the water inside. If dry inside, a boat like this would not be expected to capsize due to the weight of extra persons on one side. Partial flooding is also suggested by the damage to the bow area that was noted. Witnesses aboard the *Seaforth Highlander* recalled the damage being on the waterline one each side of the bow, "smashed inward", but the top deck appeared okay. None of the witnesses before the Marine Board stated whether or not the release hook was present in the bow (references 11b, 12). After the boat capsized, a crack was noted in the hull running fore and aft, parallel to the keel with water passing through (reference 11e). The cause of the damage to boat #2 cannot be determined from the information available for this analysis, but the damage was probably not as extensive as that to boat #1 since #2 was observed to be underway and "riding high" (references 11b, 12). Bailing a boat as extensively damaged as boat #1 would also have been a futile effort since the bow was open from gunwale to keel. Boat #1 had assumed a position in the water that would have swamped its engine.

During the *Nordertor's* attempt to recover boat #2, a rope was passed around the prop shaft resulting in the shearing of the pin that held the shaft to the engine coupling, allowing the shaft to pull out of the boat. The boat was not recovered (reference 11e). Later, two pieces of flotation foam and a thwart with its attached locker were recovered. These items were definitely identified as coming from a Harding boat since they were identical to similar components in boat #1. Boat #1 was also found not to be missing any of these components. In addition, a checklist was found in the thwart locker that contained identification of boat #2. The only way that the thwart and locker and the flotation foam could have been separated from the boat is if the boat hull had been broken apart. Since it was intact when the attempt was made by the *Nordertor* to recover the boat, it must be concluded that some time after the recovery attempt, this boat suffered extensive damage. During the two days following the attempt to recover boat #2, several sightings of half of a lifeboat were reported (references 7). This wreckage may have been part of boat #2.

LIFEBOAT #3

This is the Watercraft boat that was stowed on deck. This boat was discovered with hull intact and capsized. The cover of this boat was almost totally torn away. Recovery was accomplished by cables wrapped around the boat, and during various moves, one cable eventually cut through the hull and severed it about 1/3 length aft of the bow. This boat contained no fuel, provisions or other equipment. Many of the seat belts were still rolled-up and secured by rubber bands. The boat shows no evidence of having been occupied. It appears likely that it slid or rolled off the deck as the *Ocean Ranger* pitched forward, and that the cover was destroyed in the process. This is an opinion based on the examination of the boat and the knowledge that the boat was stowed on deck, not in its launching platform. None of the witnesses giving testimony to the Marine Board of Investigation saw this boat enter the water. Once in the water, the boat would have behaved essentially as an open lifeboat, flooding in the heavy seas and eventually capsizing. Like the Harding boats, this boat would be relatively stable in the capsized position.

LIFEBOAT #4

No trace has been found of boat #4. It could possibly still be secured to its launching platform, although one witness reported seeing no lifeboats on the stern of the *Ocean Ranger* (reference 11d). The testimony of the alternate Master of the *Ocean Ranger* stated that as of three weeks before the casualty, boat #4 had not been included in the muster list (reference 11c). If the boat had been released, or if it had broken free of its launching platform, the boat or large portions of the boat would have floated to the surface due to its inherent buoyancy. The only sightings of a lifeboat that could be connected with boat #4 were the half lifeboat sightings, although the circumstances suggest that this wreckage was in fact part of boat #2.

LIFEBOAT DESIGN AND PERFORMANCE

The primary purpose of an off-load release gear such as the Mills Gear on the Harding boats, is to allow the boat to be released when the weight of the boat is off the falls. One characteristic of the Mills Gear design is that when the weight of the boat is taken off a hook, the hook can be easily moved to the open position (even independently of the other hook) by overcoming the force of the hook counterweight. In the case of a Rottmer gear and other on-load releases approved by the U.S. Coast Guard, the hook is locked in the closed position until the operator throws the release handle. Additionally, no manufacturer of U.S. Coast Guard approved lifeboats uses a "glassed-in" connection for the keel shoe as in the Harding boat. All keel shoes are connected to the keel by through-hull bolts. The Mills type release gear operating characteristic and method of construction may have therefore led to the premature release of the aft hook of boat #1 with subsequent separation of the forward release mechanism, along with the severe damage it caused to the bow. It can not be definitely concluded that a Rottmer gear would not have failed under the same circumstances, but it would not have failed in the same way. There have been reports of lifeboats on U.S. vessels being swept away by boarding seas, so failure of a Rottmer gear under similar circumstances can not be ruled out. Even if boat #4 which is equipped with Rottmer gear is found still on the *Ocean Ranger*, it must be noted that this boat was on the aft end of the unit, and would not have been subject to the same kinds of forces experienced by boat #1.

The lifeboat installation drawings for the *Ocean Ranger* show that the boats would clear the transverse tube connecting port and starboard columns up to an adverse trim of 12°. Since the *Ocean Ranger* is believed to have gone down by the bow, boat #2 on the stern would have had to be launched against the adverse trim. If the trim exceeded 12°, or if the boat was swinging as it approached the transverse tube, some impact damage might have occurred and might account for the damage noted to boat #2. The length of the falls at the level of the transverse tube would have been approximately 100 ft. which in combination with the heavy seas would have made some swinging a realistic possibility.

In March, 1980, the Norwegian semisubmersible *Alexander L. Kielland* suffered a broken column, heeled to 30° – 35°, continued to heel until 20 minutes later when it capsized. This unit had seven totally enclosed 50 person lifeboats on board which are believed to have been essentially identical to boats #1 and #2 on the *Ocean Ranger*. The following is extracted from a summary of the report prepared by the Norwegian Government Commission investigating the casualty:

> Four of the boats were lowered without problems. However, there were problems with the release of the lifeboat hooks. The hooks, equipped with simultaneous release mechanisms, could not be disengaged under load, a circumstance difficult to avoid because of the rough seas on the day of the accident. For this reason three of the boats were blown against the platform and damaged. On the fourth boat, the after part of the wheelhouse was crushed. Through an opening caused by the impact, a man managed to release the aft hook by hand. Before that, someone had somehow succeeded in releasing the forward hook. A fifth boat fell into the water bottom-up when the platform capsized. In some unknown way, the hooks had been released. People in the boat and people outside it, managed by common effort to right it (reference 4).

The type of problems experienced with the off-load release gear and the subsequent damage to the boats in the *Alexander L. Kielland* case may be relevant in explaining the damage to *Ocean Ranger* boats #1 and #2.

Some concern was expressed in testimony that the FRP structure of the lifeboats was inadequate due to the extent of damage that was incurred (reference 11d). There is no reason to conclude this when all the damage is analyzed. The damage to the FRP in the bow of boat #1, the damage around the rear release hook, the "L" shaped fractures on either side of the bow, and possibly the damage to the helmsman's tower and hatch were apparently directly and indirectly the result of the premature release of the aft release hook. The crushing of the cover occurred when the boat was retrieved by cables. Other damage to the hull also appeared to be cable damage, some of which could have been caused by the lashing cables on the launching platform.

Boat #2 had some damage to the bow of the boat, but the reason for this can not be conclusively determined. It may have been associated with the characteristics of the release gear, impact on the transverse tube on launching, or some other unknown reason. The reason for the apparent subsequent destruction of the hull has not been determined.

The cover of boat #3 was completely torn away, but since this boat was not in a launching platform, this damage probably occurred as the boat slid or rolled off the deck. The hull was subsequently cut in two by a cable used in recovery. The hull is significantly damaged in only one other place, which was a fracture that did not penetrate the buoyancy foam and inner hull. No loss of integrity would have resulted from such damage. This damage may also have occurred when the boat came off the *Ocean Ranger*, or upon recovery.

SELF-RIGHTING OF FLOODED LIFEBOATS

After the loss of the *Ocean Express* in 1976, the U.S. Coast Guard approached the Lifesaving Appliances Subcommittee of IMCO (Inter-Governmental Maritime Consultative Organization, now International Maritime Organization – IMO) and lifeboat builders with a proposal that would require totally enclosed lifeboats to provide an above-water escape in the event of a capsizing in the flooded condition. In most cases, this would be accomplished by the addition of flotation foam to the inside of the cover, so that it would not remain underwater in the event of a capsize. This would raise the hatches on one side out of the water, and in some cases might result in re-righting of the boat. This would prevent persons inside the boat from being trapped underneath with no way out. This approach seems to be accepted by the boat builders and will probably be part of the requirements of a revised lifesaving chapter of the International Convention for the Safety of Life at Sea (SOLAS). This feature might have allowed more of the people inside the lifeboat that capsized alongside the *Seaforth Highlander* to get out of the boat, or it might have caused the flooded boat to re-right itself.

ALTERNATE LAUNCHING METHODS

The damage to lifeboat #2 may have been caused by contact with some part of the rig structure during the launching sequence. This possiblity seems even more likely when the events during the abandonment of the *Alexander L. Kielland* are considered. The type of release gear used on boats #1 and #2 is not Coast Guard approved because it will not release the boat when there is a load on the falls. Nevertheless, Coast Guard approved systems still depend on lowering by wire which can result in the lowering of the boat onto some part of the lower structure of the rig, or swinging into some part of the structure. At the present time, alternatives to lowering by wire are limited.

One new system developed in Norway allows a specially designed lifeboat to slide down a short ramp and free fall into the water. The shape of the boat, its angle of entry into the water, and the motion imparted by the ramp all work to cause the boat to move away from the casualty, even if the engine is not operating. Persons in the boat are secured in specially designed, energy absorbing, aft-facing seating. A number of these systems have been installed on Norwegian ships. The current state of the art limits this system to a launching height of approximately 20m (66 ft). Another version of the system is being developed for use on rigs. This system may be able to be used at heights of up to 30m (99 ft.). Unlike the shipboard system, no ramp would be used and the boat would drop vertically. The shape of the boat and its angle of attack would still result in movement away from the rig. The vertical drop would eliminate the swinging problem of wire systems, but it could still allow the boat to be dropped onto some part of the structure especially in the case of a boat on the high side of a listing rig. Also, if the launch is on the weather side, the boat can be driven into or under the rig as in wire launch systems.

Another system that has been considered would involve the use of some type of boom or slide that allow the survival craft to be launched well away from the structure of the rig. Such a system was proposed in the mid 1970s by the Red Adair Co., and a similar system has been recently proposed by Conoco. Such systems would seem to offer a significant improvement in the ability to launch survival craft from rigs under adverse conditions, however, neither of these systems is beyond the conceptual stage. Development of the Adair system stopped when it became evident that there would be significant structural problems. Inflatable slides have been used to launch inflatable liferafts, however, tests and observations of these systems made it evident they were not suitable for use in heavy winds and seas. At the present time, there are no known raft slide installations on any U.S. registered vessels. Nevertheless, slide or boom launch systems may offer a good launching alternative if the present problems can be overcome.

Another type of release system has been developed by the Whittaker Corp. for their survival capsules launched on single fall systems. This type of release can best be described as semi-automatic. Like the Mills gear, it uses a counterweighted hook that is designed to open when there is no load on the hook, but it is set during lowering by pulling a handle which is connected to a pin that holds the hook in place. When the boat enters the water, the load is momentarily off the hook, and it releases at that instant. If the hook is not set, and the boat becomes waterborne, or if the operator intentionally wants to release the boat before it reaches the water, a lever is provided that can be used to release the boat under load. This design is intended to combine the best features of off-load and on-load release gears. Model tests in a wave tank have shown this system to reliably provide automatic release of the boat. It is of course still a wire launch system, and therefore subject to the same limitations as other systems of that type.

LIFERAFTS

Soon after the casualty, four inflatable liferafts were recovered. One raft was complete with some damage to its canopy and damage to one of the inflation tubes which occurred during recovery. Another raft was complete, but the upper and lower tube had separated from each other over about 75% of the circumference of the raft and some damage to the canopy. The third raft was complete with its floor separated about 80% of its circumference. The floor became completely separated in the process of moving and inspecting the raft. The fourth raft consisted only of an upper buoyancy tube and canopy support, and a floor which was completely separated from the tube except for the inflation hose connection. This raft's canopy and lower buoyancy tube are missing. One of the witnesses reported seeing one partially inflated raft and two fully inflated rafts, one of which was blowing over and over. It is not known if any of these rafts were recovered. One raft was observed to sink the day after the casualty, and another five days after (references 7, 8). A sunken raft was recovered in June 1982 about 60 miles from the scene of the casualty at a location different from the sites where the other two rafts were seen sinking. The five recovered rafts and the two sunken rafts not recovered account for seven of the ten rafts aboard the *Ocean Ranger*, although there is a chance that one of the rafts sighted but not recovered was one lost from the *SEDCO 706* several hours before the sinking of the *Ocean Ranger* (reference 11a).

Three of the rafts and the separated floors had separated at the joints that hold the floor to the buoyancy tubes and that hold the buoyancy tubes to each other. Only one of the painter lines was complete from the raft to the point of the weak link. The other painters were severed at a point short of the weak link. Some damage to the rafts was incurred on recovery. Testimony from persons on-scene indicates that some rafts were properly inflated and others were damaged before they were picked up. One was described as being a few bubbles of jumbled liferaft material with ropes wrapped around it (references 11d, 11e).

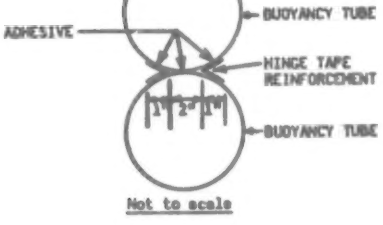


FIGURE 3 Normal construction of liferaft.

There was no evidence that suggests that the rafts were ever occupied. Some equipment bags were open, but since they were made to be readily opened, this is not significant. There was no evidence of the use of flares. None of the liferaft relief valves had plugs screwed into them. While this would not necessarily be done by survivors, any plug found in a relief valve would suggest that the raft had been occupied since the rafts are packed with the plugs out of the valves. All doors were tied in the open position the way they should be when packed.

LIFERAFT DESIGN AND PERFORMANCE

Nine of the ten rafts involved were built in 1974 for C.J. Hendry Co., of San Francisco, California. The tenth raft was a B.F. Goodrich raft which was one of the rafts not recovered. Inflatable liferafts are typically considered to last roughly 10 years, so these rafts may have been nearing the end of their useful lives. Because of the extent of joint separation, attention was focused on the performance of the joints and adhesive. Raft seams are required to have a strength greater than that of the base fabric, however, these requirements are intended primarily for the seams in the buoyancy tubes, rather than the joints that assemble tubes, floor, and canopy into a complete raft. The joints between upper and lower buoyancy tubes and between buoyancy tube and floor were the primary problem areas. Joint samples have been cut from the recovered rafts and tests are to be performed on them by Technitrol Canada, Dorval, Quebec. At this writing, those tests have not been completed. *[Editors Note: The Technitrol Canada Ltd. report, Exhibit # 224, revealed that none of the samples taken from the Ocean Ranger Liferafts met the British Department of Trade specifications for joint strength. No American specification existed for this type of test.]*

Examination of the areas of the raft that had joint separation showed in most cases, adhesive adhered to one side of the joint, but not the other. Failure appeared to be in the peel mode, but it could not be conclusively determined by examination where the peeling began or why. Glued joints are generally weakest in the peel mode. Figure 3 illustrates the normal method of joining upper and lower tubes. On raft 715, the central area shown as 2 in. wide in the figure was actually much narrower and did not have any evidence of adhesive joining upper and lower tubes directly. Adhesive was evident only on the reinforcement. If the tubes are directly joined, forces tending to separate upper and lower tubes would be resisted by a tensile load on the adhesive joining the tubes. As built, the forces pulling the tubes apart are resisted by the reinforcing tape in the peel mode. If the tubes had been joined in the central area, the resulting structure may have been more resistant to separation.

In its examination of the rafts, Technitrol Canada repaired some of the ripped tubes and attempted to inflate the rafts. Several rafts showed blistering where inner and outer coating had separated from the base fabric. Some of these blisters exhibited pinhole leaks. It has not been determined how or when these blisters occurred, or if they contributed to deflation of some of the rafts soon after the casualty.

In order that inflatable liferafts function properly when needed, they are required to be serviced annually by an approved service station. According to the records, the rafts on the *Ocean Ranger* were serviced between 20 April 1981 and 31 July 1981 by an organization in St. John's, Newfoundland (reference 3). This organization was not an approved servicing facility for either C.J. Hendry or B.F. Goodrich rafts and as such would probably not have had the necessary repair parts, manuals, servicing bulletins and packing instructions. A raft which is improperly serviced may not inflate or deploy properly, leading to rafts which can not be used. There were and are no approved servicing facilities in St. John's for U.S. Coast Guard approved rafts. The closest facility was in the Boston, Massachusetts area.

One of the problems with inflatable liferafts that has been recognized for some time is their tendency to be carried away from the scene of an accident before survivors can reach them, and to capsize in high winds and heavy seas. In recent years, a new type of "heavily ballasted" liferaft has been developed and promoted primarily for its resistance to capsizing in heavy seas. In an Advance Notice of Proposed Rulemaking dated 29 June 1981, the U.S. Coast Guard announced that it was considering amendment of the approval requirements for inflatable liferafts to include requirements for such ballast systems. Capsizing of liferafts has been recognized as a problem, but if no one can reach the raft in the first place it is only an academic interest. Perhaps a more important characteristic of such rafts is their tendency to drift with the current rather than being carried away at high speed by wind and waves. Survivors in the water will also drift with the current, so the probability that survivors could reach the rafts is increased.

Even if all of the rafts had floated free, inflated, and had been in the vicinity of persons in the water, it is doubtful that many persons would have been able to reach and board them, although those wearing helicopter-type immersion suits would have had a better chance (see following discussion of exposure protection). The paralyzing effect of the cold water would have made it difficult for anyone in the water without exposure protection to pull themselves aboard a raft. This was illustrated by the inability of any of the persons that entered the water alongside the *Seaforth Highlander* to board the liferaft deployed by that vessel or to assist themselves in any way (references 11b, 12). Some type of effective personal hypothermia protection would have to be provided in order for these persons to help themselves to the extent necessary to board a liferaft.

The fact at least three rafts sank should not be taken as conclusive evidence that they were severely damaged. These rafts are equipped with relief valves to prevent the raft from exploding due to a pressure build-up from excess inflation gas. Once inflated and boarded, occupants should plug the relief valves to prevent loss of gas as the raft flexes in the waves. Unoccupied rafts may eventually deflate even if undamaged. It is not possible to conclusively determine what happened to the liferafts. In the opinion of the author, the available evidence suggests one or a combination of the following may explain why some rafts were damaged before they were recovered:

a. The liferafts may have floated free of their stowed positions as the *Ocean Ranger* sank. A few became entrapped in the rigging and appendages of the unit and never got to the surface. Others did inflate and rise to the surface, but some were damaged as they came in contact with various parts of the structure. This would account for damage to the raft joints and severed painter lines.

b. The liferafts may have floated free of their stowed positions, inflated, and risen to the surface. Some of the rafts had aged sufficiently to cause deterioration in the glued joints. These rafts then suffered damage in the heavy seas.

c. The liferafts may have floated free of their stowed positions, inflated, and risen to the surface. The joints had not significantly deteriorated, but the joint design was not adequate for the stresses encountered. These rafts then suffered damage in the heavy seas.

d. The rafts may not have been properly serviced and repacked, leading to non-inflation in some cases, and damage upon inflation in other cases.

e. Rafts damaged as described above would have been readily swamped. When swamped, these rafts would have behaved in a manner similar to heavily ballasted liferafts, drifting with the current and staying near the site of the casualty. Undamaged rafts would have been quickly carried away from the scene by the wind and waves, so that they were difficult to locate by the time daylight arrived.

DAVIT LAUNCHED LIFERAFTS

Under Title 46 of the Code of Federal Regulations, SS108.506 and NVC 3-78, sec. 3.d.(8), the *Ocean Ranger* was required to have a combination of lifeboats and davit launched inflatable liferafts sufficient to accommodate 200% of the persons on board. The owner intended to comply with this requirement by the addition of the Watercraft lifeboats, which in combination with the Harding lifeboats would bring total lifeboat capacity to 200% (references 11b, 6). This solution did not address the fact that the Harding lifeboats were not acceptable under Coast Guard regulations or under NVC 10-81.

In order to fully comply with the Coast Guard requirements, the owner would have had to replace or upgrade the Harding lifeboats, or else remove them and replace the liferafts with davit launched liferaft installations. Had davit launched liferafts been on board, these could have been boarded and launched from the deck in a manner similar to the lifeboats. The approved release hook system automatically releases the raft when the hook is set during lowering and the raft becomes waterborne. Operation of the hook is similar to the system described for the Whittaker survival capsules in a preceding section, except that it may not be possible to release the raft when the hook is loaded. The davit launching system would have made the liferafts more readily available for use since the conventional liferafts could not be boarded until they were waterborne and inflated. On a rig like the *Ocean Ranger* or any vessel with a high freeboard, this is a very difficult operation, made more difficult by the weather, sea state, and sea temperature. On the other hand, the davit launched liferafts are subject to the same launching problems on MODUs as the lifeboats are. The air gap under the rig results in full exposure to wind and sea regardless of where located, and there is the risk that the raft will be driven into some part of the structure during or after launching. Nevertheless, since davit launched liferafts would have been more likely to have been boarded than the conventional rafts, it follows that they could possibly have saved some lives.

LIFE PRESERVERS

Of the bodies recovered after the casualty, 21 were wearing Billy Pugh Model 200 life preservers and one was wearing a Billy Pugh Model WV0-100 work vest. All but two of the life preservers were equipped with ACR model L8-2 water-activated personal flotation device lights. The lights apparently worked well and were useful for locating persons in the water. Many of the bodies (actual number unknown) were found face-down and some were underwater, hanging by the body strap underneath the floating life preserver (references 11b, 11d). Under the latter circumstances, the life preserver apparently came off over the head of the wearer who did not put it back on, indicating that when the life preserver came off, the wearer was already dead or was unable to help himself due to the effects of hypothermia.

The Billy Pugh Model 200 life preservers that were recovered were examined and were found to fall into two distinctly separate groups. One group of devices that came from lot 1A were noticeably heavier than the other devices and were of a different design. The other group was comprised of devices from various lots produced later than lot 1A. The initial certificate of approval for the Model 200 was issued 17 February 1977, however, the lot 1A devices were inspected and passed by a Coast Guard inspector from the Corpus Christi, TX, Marine Safety Office on 15 July 1976. These devices had the Coast Guard approval number on them because the manufacturer had been told what the approval number would be. This is frequently done in advance of actual approval so that the manufacturer can plan equipment markings and promotional material. The fact that they were inspected and passed by a Coast Guard inspector would indicate that they were found to have the proper buoyancy and to conform with the manufacturer's plans and specifications, although this inspection marking is usually not applied until a device is actually approved. Nevertheless, the lot 1A devices were a pre-approval design of 98 units and would not normally have been sold or used as Coast Guard approved devices. It is not known how these devices came to be released.

One pre-approval Model 200 was tested by Coast Guard Headquarters personnel in May 1976. At that time, a tendency for the device to come off over the wearer's head when jumping into the water was noted, but the turning moment (the force that turns the wearer from a face-down to a face-up position) appeared to be acceptable (reference 13). In August, 1976, the company was informed that the device fell short of life preserver performance requirements in that it had a lack of turning moment and that it did not keep the wearer's head far enough out of the water (reference 14). The differences in the designs tested at these two times and their exact relationship with the lot 1A design are not known, however, sketches enclosed with the August 1976 letter show a design similar to the lot 1A design. The design finally approved in February 1977 resolved these problems sufficiently to allow its approval (reference 9). The Model 200 devices from the *Ocean Ranger* that were from lots other than 1A appear to conform with the approved design. No correlation between bodies found face-down and those wearing lot 1A devices can be made from the information available for this analysis.

Rough water performance of life preservers has recently become a matter of concern to the Coast Guard. The person in the water will not rise as fast as the water on the face of a wave and therefore may be submerged momentarily. Depending upon the combination of person, life preserver and sea state, this may develop into a plunging action. One witness reported the heads of the persons in the water constantly washing underwater (reference 12). On yoke-type life preservers like the Billy Pugh devices, this action may result in the life preserver being pulled off over the head if the device is not secure under the chin or around the body. One of the tests that has been used to determine the acceptability of life preservers is a jump test from a height of 3 m into a pool. Although this is intended as a test of the performance of the life preserver when the wearer is jumping into the water, it may also prove to be useful in evaluating the tendency of the device to come off in rough water. During the approval testing of the Model 200 (approved version), 26 persons performed the jump test in the device. It came off over the heads of three of the test subjects and tended to ride up on a fourth. These subjects jumped a second time wrapping their arms around the device (a procedure generally recommended for jumping into the water in any life preserver), and in each case it stayed on. The test report does not record the way in which the body strap was adjusted (reference 9). Recently, as part of the *Ocean Ranger* lifesaving analysis, a Model 200 (approved design) was subjected to the jump test on five different test subjects. With the body strap secured tightly, the device tended to rise to the subject's eye or ear level, but did not come off. With the body strap adjusted to a "comfortable" position as judged by the subject, the device came off over the heads of four out of the five subjects. The same test was performed with a yoke-type life preserver of "standard" design which was found to stay on the same subjects with the body strap in the tight and also in the comfortable positions.

Samples of the Model 200 life preservers from the *Ocean Ranger* were obtained and subjected to further examination and a buoyancy test (reference 10). Examination of the devices and Coast Guard files indicates that the lot 1A devices are made of polyvinyl chloride (PVC) flotation foam rather than polyethylene (PE) foam as prescribed for the approved design. The PVC has a higher density which accounts for the apparent weight difference in the two groups of devices. The neck opening in the lot 1A devices is of a different design and slightly larger than the approved design. PVC foam is also more flexible than PE foam, and the flotation pads on the lot 1A devices are thinner than on the approved devices. All of these factors would contribute to the tendency to allow the wearer's head to slip out of the lot 1A devices. The buoyancy test showed that the lot 1A devices had a buoyancy loss of about 6-1/2% as compared to their original buoyancy. One of the three lot 1A devices tested was 1 oz. under the 22 lb. minimum buoyancy required for new devices. The other two were 6 oz. under the minimum. Some degradation of life preserver buoyancy is expected with age, and the losses on these devices would not be considered critical. The other three devices of the approved design were all above the 22 lb. minimum by 1 oz., 27 oz., and 28 oz.

As a result of these findings, the manufacturer of the life preservers was advised that the unapproved devices had been discovered to be in use and should be recalled or destroyed. The manufacturer's approval of the device was suspended pending improvement in its performance in the jump test (reference 16). The manufacturer did institute a voluntary recall of devices from lots 1 and 1A, comprising 172 unapproved devices (reference 1). The design of the approved device was also altered so that it performs properly in the jump test. The approval certificate was subsequently reinstated.

EXPOSURE PROTECTION

At least two of the bodies recovered were wearing some type of exposure protection garment. In photographs, these appeared to be uninsulated immersion suits of the type sometimes used on offshore helicopters. A quantity of these suits issued by the helicopter operator were normally kept on board the *Ocean Ranger*. These devices were apparently returned as personal effects and were not available for examination. It was reported that at least one person in one of these suits sank when he came out of his life preserver (reference 12). Unlike the U.S. Coast Guard approved exposure suits, these devices do not have the buoyancy and insulation provided by flotation foam. They are waterproof garments that must be used in conjunction with a life preserver. The purpose of these garments is to keep the wearer dry, so that loss of body heat through direct contact with the water is prevented. To protect from conductive heat loss through the suit, as much clothing as possible should be worn underneath the suit.

One recent study compared heat loss rates of different types of exposure protection in calm 11.8°C (54°F) water. All of the test subjects wore the same type of clothing – underwear, long sleeve shirt, denim trousers, socks and sneakers. The average cooling rate for the subjects wearing only a life preserver in addition to the basic clothing ensemble was 2.30°C/hr. Subjects wearing uninsulated immersion suits averaged 1.07°C/hr. loss rate (2.15 time "better" than the subjects with only a life preserver). Those wearing insulated exposure suits averaged a loss rate of 0.31°C/hr. (7.35 times "better" than the subjects with only a life preserver). This study also estimated the time to "incipient death" with different types of exposure protection in the 11.8°C water. For those in life preservers, this time was 3.4 hr. For those in uninsulated immersion suits, it was 7.0 hr. For insulated exposure suits, it was 23.1 hr. (reference 2).

From this data, it can be seen that those persons wearing the immersion suits should have been able to survive perhaps twice as long as those with life preservers alone. These suits obviously did not provide the margin of exposure protection needed in the conditions that existed following the abandonment of the *Ocean Ranger*. Insulated exposure suits of the type that are U.S. Coast Guard approved might have extended survival time six or seven times that of persons wearing life preservers alone.

EMERGENCY RADIO COMMUNICATION EQUIPMENT

An ACR RLB-14 Emergency Position Indicating Radio Beacon (EPIRB) was on board the *Ocean Ranger*. It was recovered after the casualty indicating that it had floated free. The signal from the EPIRB was received by rescue aircraft flying to the site of the casualty, however, since the standby boats had already been alerted to the problems being experienced by the *Ocean Ranger* and since its position was known, the EPIRB did not appear to be a factor in this casualty.

A JVC portable lifeboat radio (Japanese – not FCC approved) was found in boat #1. There was no evidence that indicates any attempt was made to use this radio.

A VHF-FM two-way radio was also found inside boat #1. There were no radio transmissions during the casualty identified as having come from this radio.

REFERENCES

1. Billy Pugh Co., letter, "Recall Model #200 Life Preservers Lot 1 and Lot 1A," 12 October 1982.

2. J.S. Hayward, et al., "Survival Suits for Accidental Immersion in Cold Water: Design-Concepts and their Thermal Protection Performance", University of Victoria, Victoria, B.C., Canada, January 1978.

3. IMP Group Ltd., Liferaft Certificates of Inspection, *Ocean Ranger* Marine Board of Investigation file 4.57A.

4. Torgeir Moan, "The *Alexander L. Kielland* Accident," proceedings from *The First Robert Bruce Wallace Lecture*, Massachusetts Institute of Technology, June 1981. p. 12.

5. *Ocean Ranger* telex to ODECO, St. John's and New Orleans offices, dated 11 January 1982, U.S. Coast Guard Marine Board of Investigation Exhibit 47.

6. Ocean Drilling and Exploration Co., letter to Commander (mmt), Eighth Coast Guard District, dated 14 January 1980, U.S. Coast Guard Marine Board of Investigation Exhibit 12p.

7. Rescue Co-ordination Center Halifax, Nova Scotia, "Search and Rescue Special Report, SAR *Ocean Ranger*," p. 9/2, 20/6, undated.

8. *SEDCO 706* Radio Log, U.S. Coast Guard Marine Board of Investigation Exhibit 11.

9. Underwriters Laboratories, letter, "Performance Testing of Billy Pugh Adult Life Jackets," 12 November 1976.

10. Underwriters Laboratories, letter, "Test Results: Weight Determination and Buoyancy Tests on Six Billy Pugh PFD's," 19 August 1982.

11. U.S. Coast Guard, Marine Board of Investigation. *Certified Transcript of Proceedings in the Matter of Investigation of the Sinking of the Mobile Offshore Drilling Unit Ocean Ranger in the Atlantic Ocean on 15 February 1982.*

a. Volume III, p. 15, testimony of Donald King, 20 April 1982.

b. Volume IV, pp. 15, 17, 18-20, 40, 41, 45, 74, 78, 156, testimony of Rolf W. Jorgensen, 21 April 1982.

c. Volume V, pp. 24-25, 36, testimony of Geoffrey Dilks, 22 April 1982.

d. Volume VIII, pp. 27, 33, 37, 47, 84-85, testimony of James Davison, 27 April 1982.

e. Volume VIII, pp. 97-100, 101, 106-107, testimony of Baxter Allingham, 27 April 1982.

f. Volume XI, testimony of Kelvin Gernandt, 7 June 1982.

g. Volume XII, pp. 31-34, 38, testimony of Ronald Green, 8 June 1982.

h. Volume XVI, p. 34, deposition of Thomas Kane, 21 July 1982.

12. U.S. Coast Guard, Marine Board of Investigation. *Investigation of the Sinking of the Mobile Offshore Drilling Unit Ocean Ranger in the Atlantic Ocean on 15 February 1982* transcript, Exhibit 53A, pp. 10, 11-12, 25-26, 29, 31, 33, deposition of Ronald Duncan, 21 May 1982.

13. U.S. Coast Guard (G-MMT-3), memorandum, "Swim Test Results," file 5946/160.055/113, 6 May 1976.

14. U.S. Coast Guard (G-MMT-3), letter to Billy Pugh Co., file 16714/160.053/GENERAL, 2 August 1976.

15. U.S. Coast Guard Marine Inspection Office, Providence, RI, letter to Ocean Drilling and Exploration Co., dated 18 December 1979, U.S. Coast Guard Marine Board of Investigation Exhibit 12i.

16. U.S. Coast Guard (G-MVI-3), letter to Billy Pugh Co., file 16714/160.055/113, 22 September 1982.

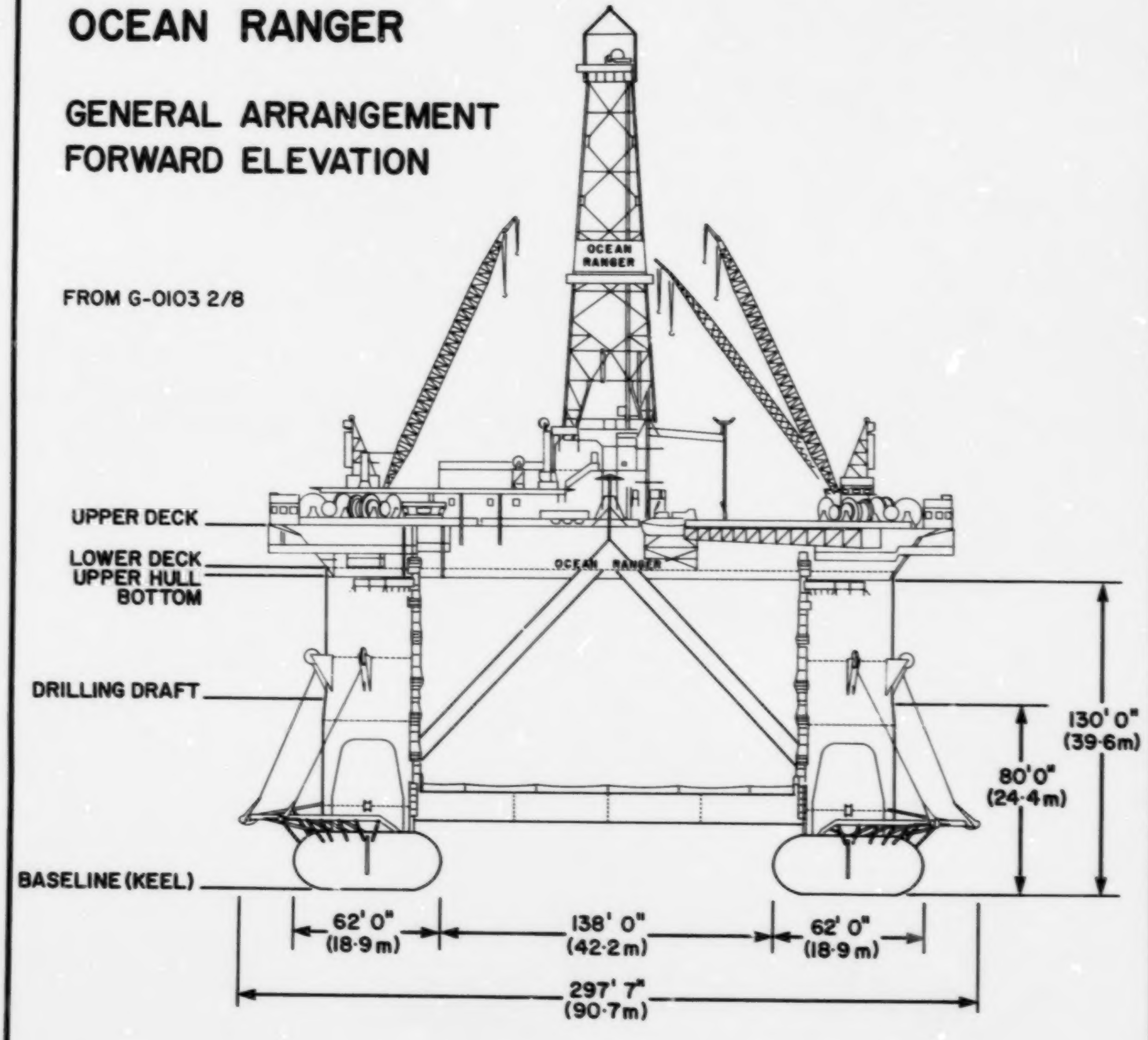
17. United States Testing Co., Inc., "Report of Test; Seat Belt Assemblies," Test Number 83428-82, 19 August 1982.

Item F-7
Technical Drawings

OCEAN RANGER

GENERAL ARRANGEMENT FORWARD ELEVATION

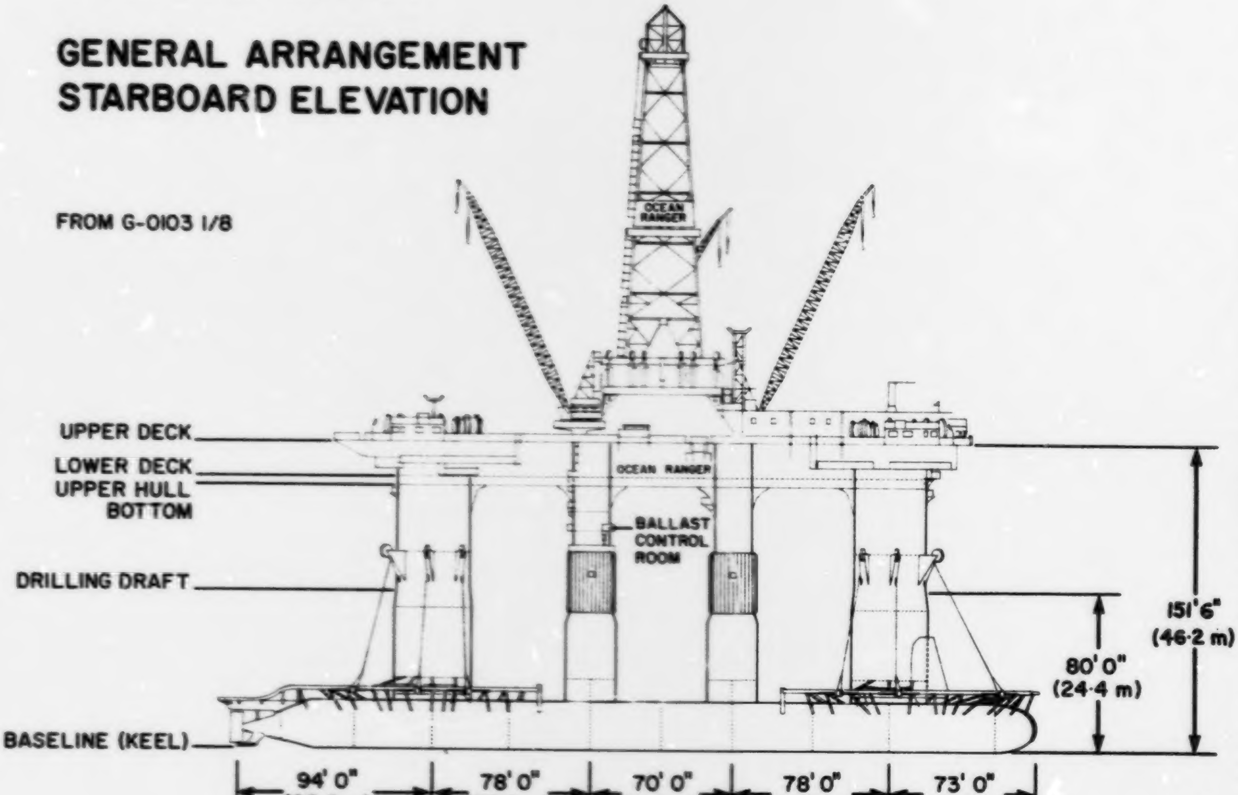
FROM G-0103 2/8


OCEAN RANGER
UPPER DECK
LOWER DECK
UPPER HULL BOTTOM
OCEAN RANGER
DRILLING DRAFT
130' 0" (39·6m)
80'0" (24·4m)
BASELINE (KEEL)
62' 0" (18·9m)
138' 0" (42·2m)
62' 0" (18·9m)
297' 7" (90·7m)

OCEAN RANGER

GENERAL ARRANGEMENT STARBOARD ELEVATION

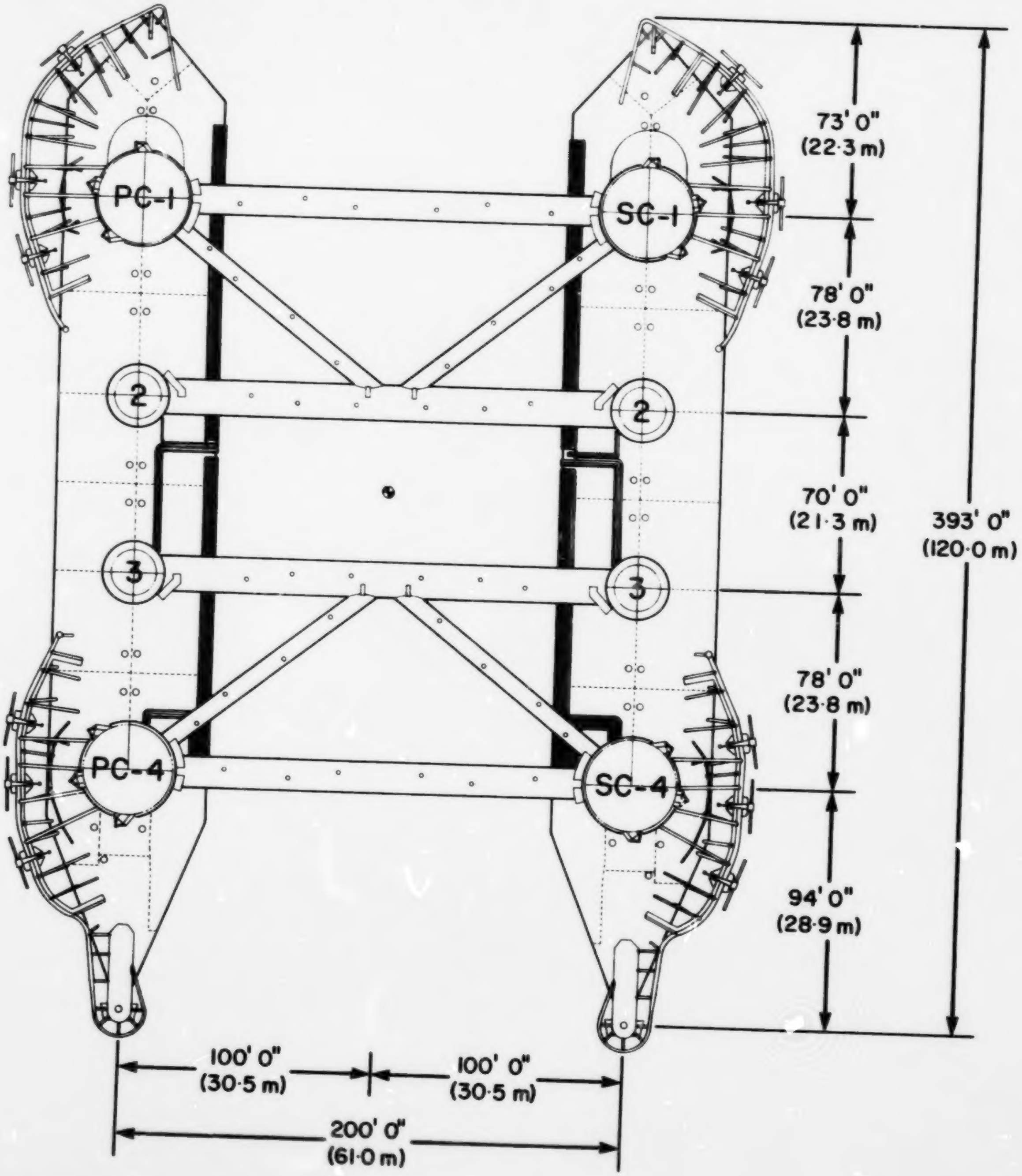
FROM G-0103 1/8


OCEAN RANGER
UPPER DECK
LOWER DECK
UPPER HULL BOTTOM
OCEAN RANGER
BALLAST CONTROL ROOM
DRILLING DRAFT
BASELINE (KEEL)
151'6" (46·2 m)
80' 0" (24·4 m)
94' 0" (28·9 m)
78' 0" (23·8 m)
70' 0" (21·3 m)
78' 0" (23·8 m)
73' 0" (22·3 m)
393' 0" (120·1 m)

OCEAN RANGER

GENERAL ARRANGEMENT
LOWER HULL EXTERIOR FITTING

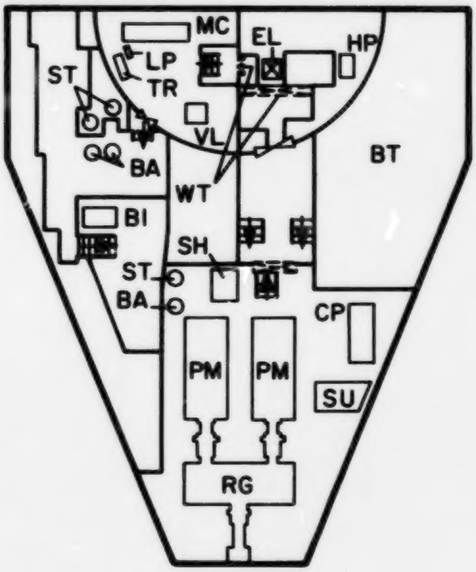
FROM G-0103 3/8


PC-1
SC-1
2
2
3
3
PC-4
SC-4
73' 0" (22·3 m)
78' 0" (23·8 m)
70' 0" (21·3 m)
78' 0" (23·8 m)
94' 0" (28·9 m)
393' 0" (120·0 m)
100' 0" (30·5 m)
100' 0" (30·5 m)
200' 0" (61·0 m)

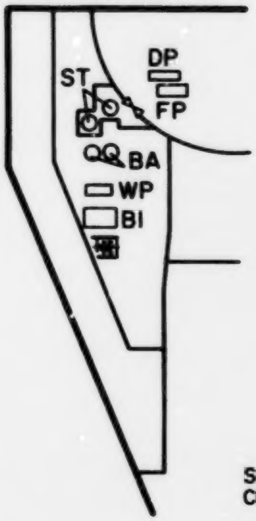
OCEAN RANGER

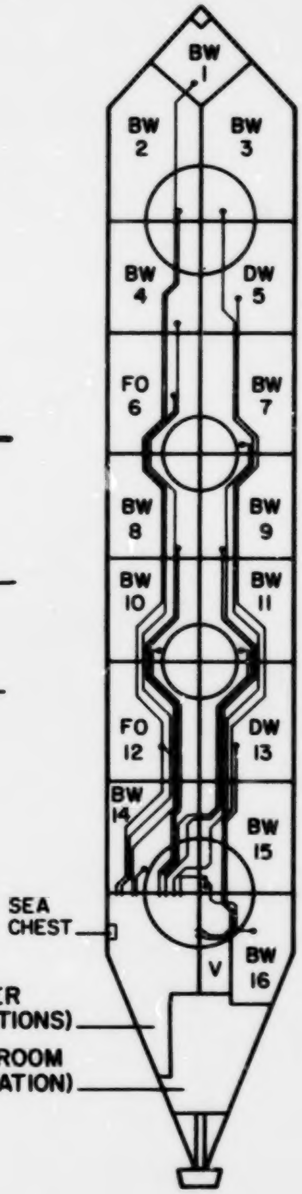
PUMP AND PROPULSION ROOMS (STARBOARD PONTOON)

UPPER ELEVATION


MC
EL
HP
LP
TR
ST
VL
BA
BT
WT
BI
SH
ST
BA
CP
PM
PM
SU
RG

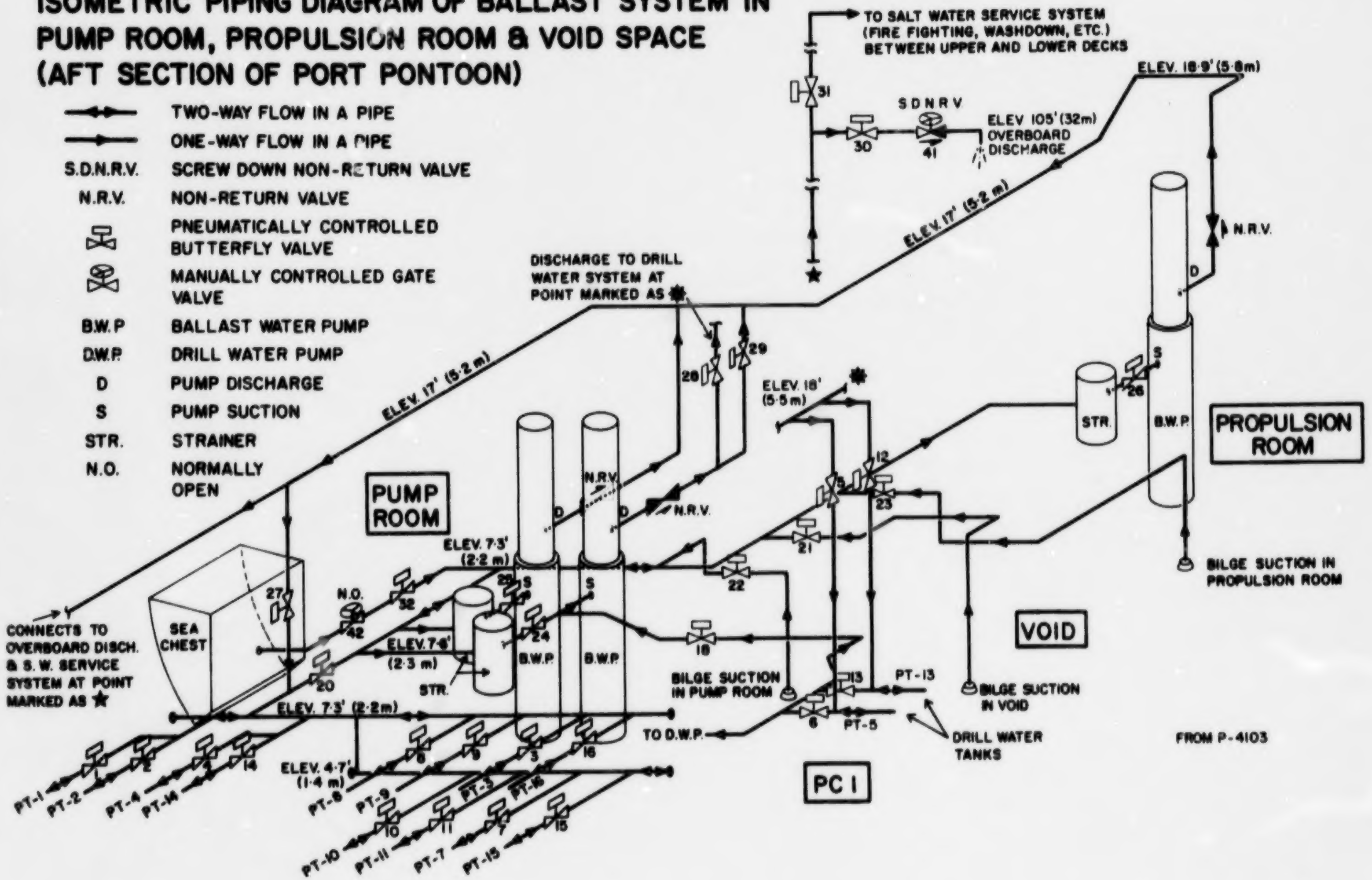
LOWER ELEVATION


DP
ST
FP
BA
WP
BI


BW 1
BW 2
BW 3
BW 4
DW 5
FO 6
BW 7
BW 8
BW 9
BW 10
BW 11
FO 12
DW 13
BW 14
BW 15
SEA CHEST
V
BW 16
PUMP ROOM (LOWER AND UPPER ELEVATIONS)
PROPULSION ROOM (UPPER ELEVATION)

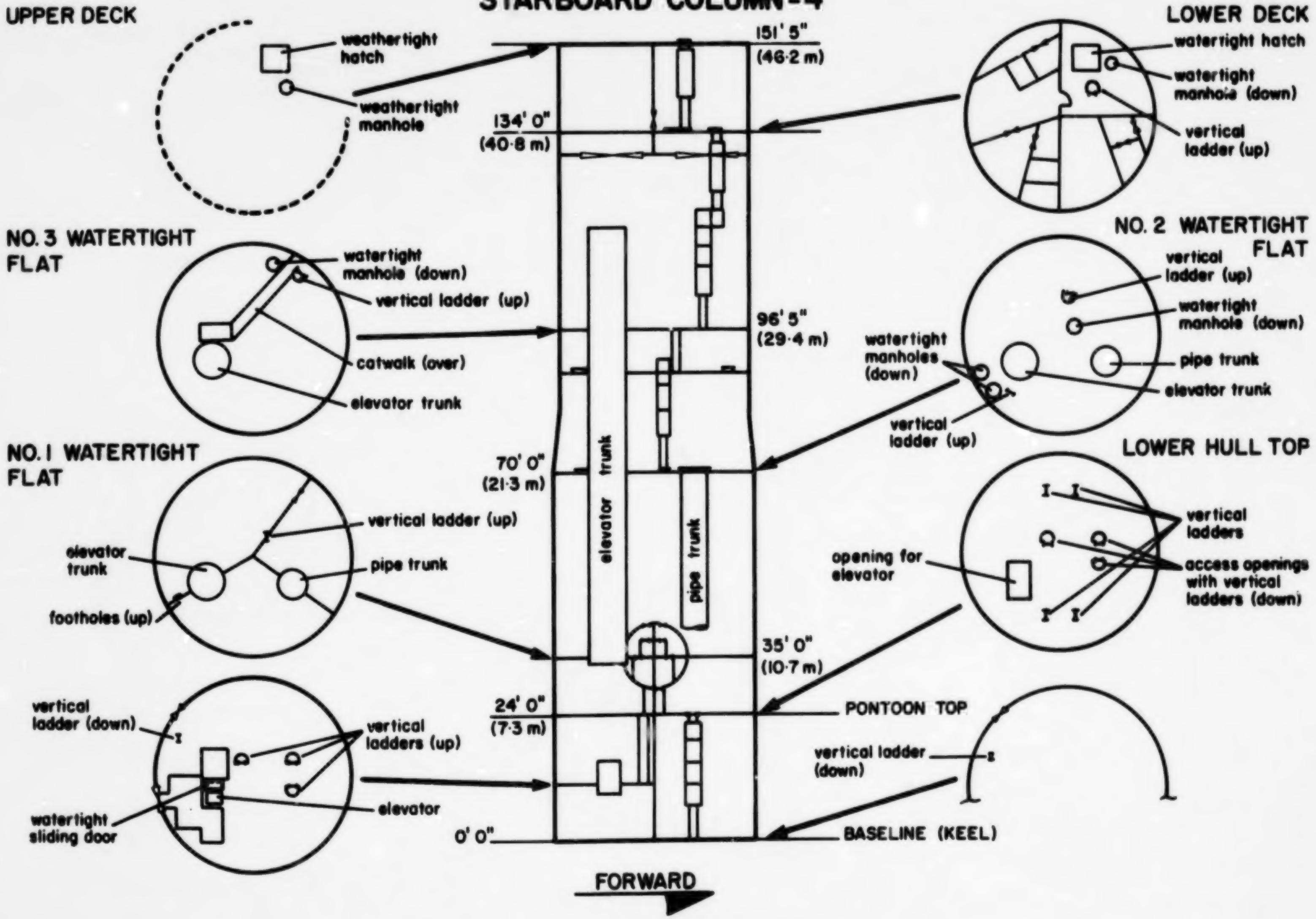
BA	BALLAST WATER PUMP
BI	BILGE PUMP
BT	BALLAST TANK
CP	CONTROL PANEL
DP	DRILL WATER PUMP
EL	ELEVATOR
FP	FUEL PUMP
HP	HYDRAULIC PUMP UNIT
LP	LIGHTING PANEL
MC	MOTOR CONTROL CENTRE
PM	PROPULSION MOTOR
RG	REDUCTION GEAR
SH	STEERING HYDRAULIC UNIT
ST	STRAINER
SU	SUMP TANK
TR	TRANSFORMER
VL	VERTICAL LADDER
WP	PROPULSION MOTOR COOLING WATER PUMP
WT	WATERTIGHT SLIDING DOOR
•	SUCTION BELL MOUTH
BW	BALLAST WATER
DW	DRILL WATER
FO	FUEL OIL
V	VOID

OCEAN RANGER
ISOMETRIC PIPING DIAGRAM OF BALLAST SYSTEM IN PUMP ROOM, PROPULSION ROOM & VOID SPACE (AFT SECTION OF PORT PONTOON)


TWO-WAY FLOW IN A PIPE
ONE-WAY FLOW IN A PIPE
S.D.N.R.V. SCREW DOWN NON-RETURN VALVE
N.R.V. NON-RETURN VALVE
PNEUMATICALLY CONTROLLED BUTTERFLY VALVE
MANUALLY CONTROLLED GATE VALVE
B.W.P BALLAST WATER PUMP
D.W.P DRILL WATER PUMP
D PUMP DISCHARGE
S PUMP SUCTION
STR. STRAINER
N.O. NORMALLY OPEN
TO SALT WATER SERVICE SYSTEM (FIRE FIGHTING, WASHDOWN, ETC.) BETWEEN UPPER AND LOWER DECKS
31
S D N R V
30
41
ELEV 105' (32m) OVERBOARD DISCHARGE
ELEV. 18·9' (5·8m)
ELEV. 17' (5·2 m)
N.R.V.
D
DISCHARGE TO DRILL WATER SYSTEM AT POINT MARKED AS ✱
29
28
ELEV. 18' (5·5 m)
S
26
STR.
B.W.P.
PROPULSION ROOM
12
23
21
22
N.R.V.
D
D
N.R.V.
PUMP ROOM
ELEV. 7·3' (2·2 m)
25
S
S
B.W.P.
B.W.P.
24
27
N.O.
42
32
ELEV. 7·6' (2·3 m)
STR.
18
BILGE SUCTION IN PROPULSION ROOM
VOID
CONNECTS TO OVERBOARD DISCH. & S. W. SERVICE SYSTEM AT POINT MARKED AS ★
SEA CHEST
20
BILGE SUCTION IN PUMP ROOM
13
PT-13
BILGE SUCTION IN VOID
ELEV. 7·3' (2·2m)
6
PT-5
TO D.W.P.
DRILL WATER TANKS
FROM P-4103
1
2
4
14
8
9
3
16
ELEV. 4·7' (1·4 m)
PT-1
PT-2
PT-4
PT-14
PT-8
PT-9
PT-3
PT-16
PC I
10
11
7
15
PT-10
PT-11
PT-7
PT-15

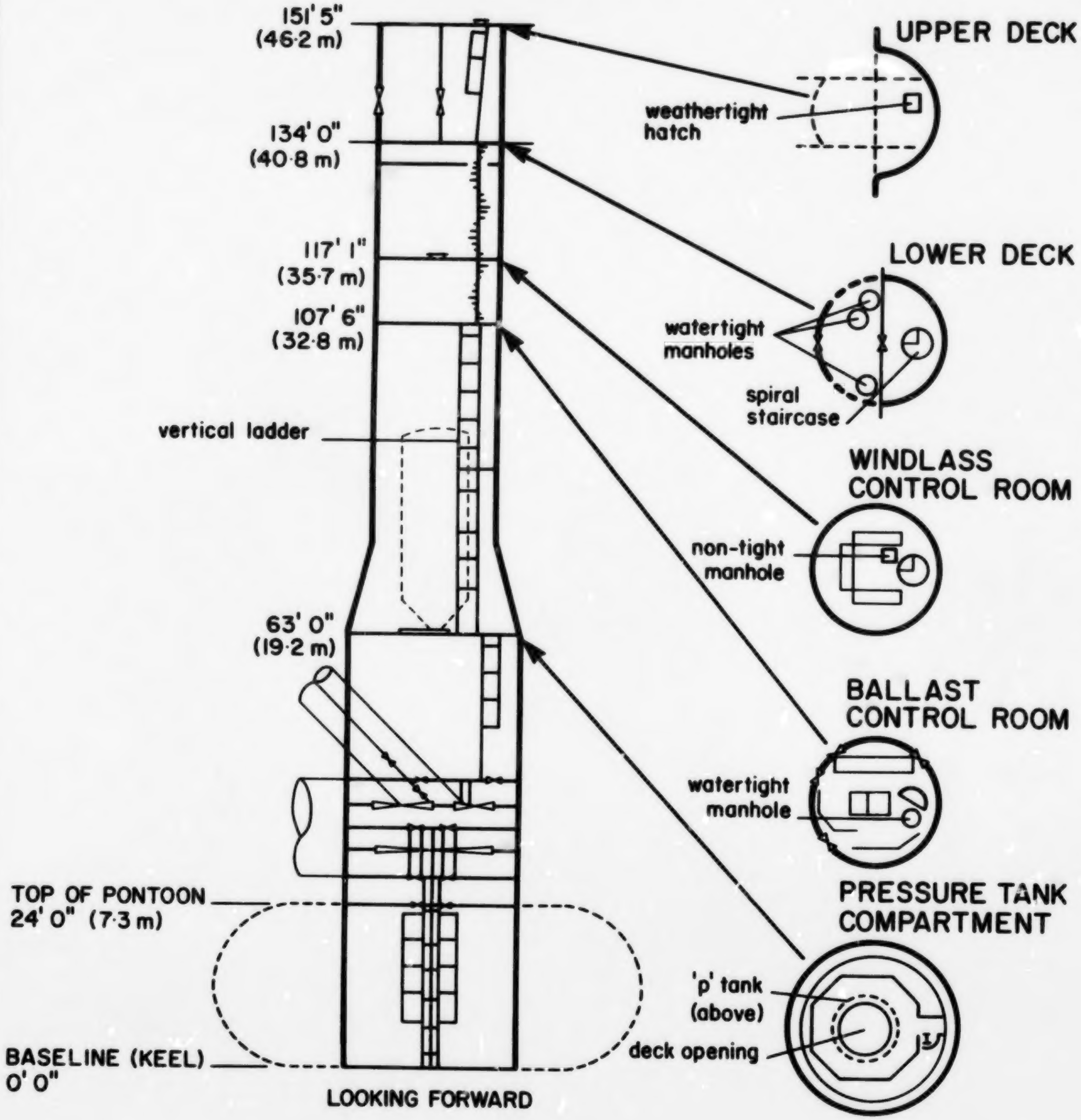
OCEAN RANGER
STARBOARD COLUMN-4

FROM G-0103 8/8


UPPER DECK
weathertight hatch
weathertight manhole
NO. 3 WATERTIGHT FLAT
watertight manhole (down)
vertical ladder (up)
catwalk (over)
elevator trunk
NO. 1 WATERTIGHT FLAT
vertical ladder (up)
elevator trunk
pipe trunk
footholes (up)
vertical ladder (down)
vertical ladders (up)
watertight sliding door
elevator
151' 5"
(46·2 m)
134' 0"
(40·8 m)
96' 5"
(29·4 m)
70' 0"
(21·3 m)
35' 0"
(10·7 m)
24' 0"
(7·3 m)
0' 0"
elevator trunk
pipe trunk
PONTOON TOP
BASELINE (KEEL)
FORWARD
LOWER DECK
watertight hatch
watertight manhole (down)
vertical ladder (up)
NO. 2 WATERTIGHT FLAT
vertical ladder (up)
watertight manhole (down)
watertight manholes (down)
pipe trunk
elevator trunk
vertical ladder (up)
LOWER HULL TOP
vertical ladders
opening for elevator
access openings with vertical ladders (down)
vertical ladder (down)

OCEAN RANGER
STARBOARD COLUMN-3

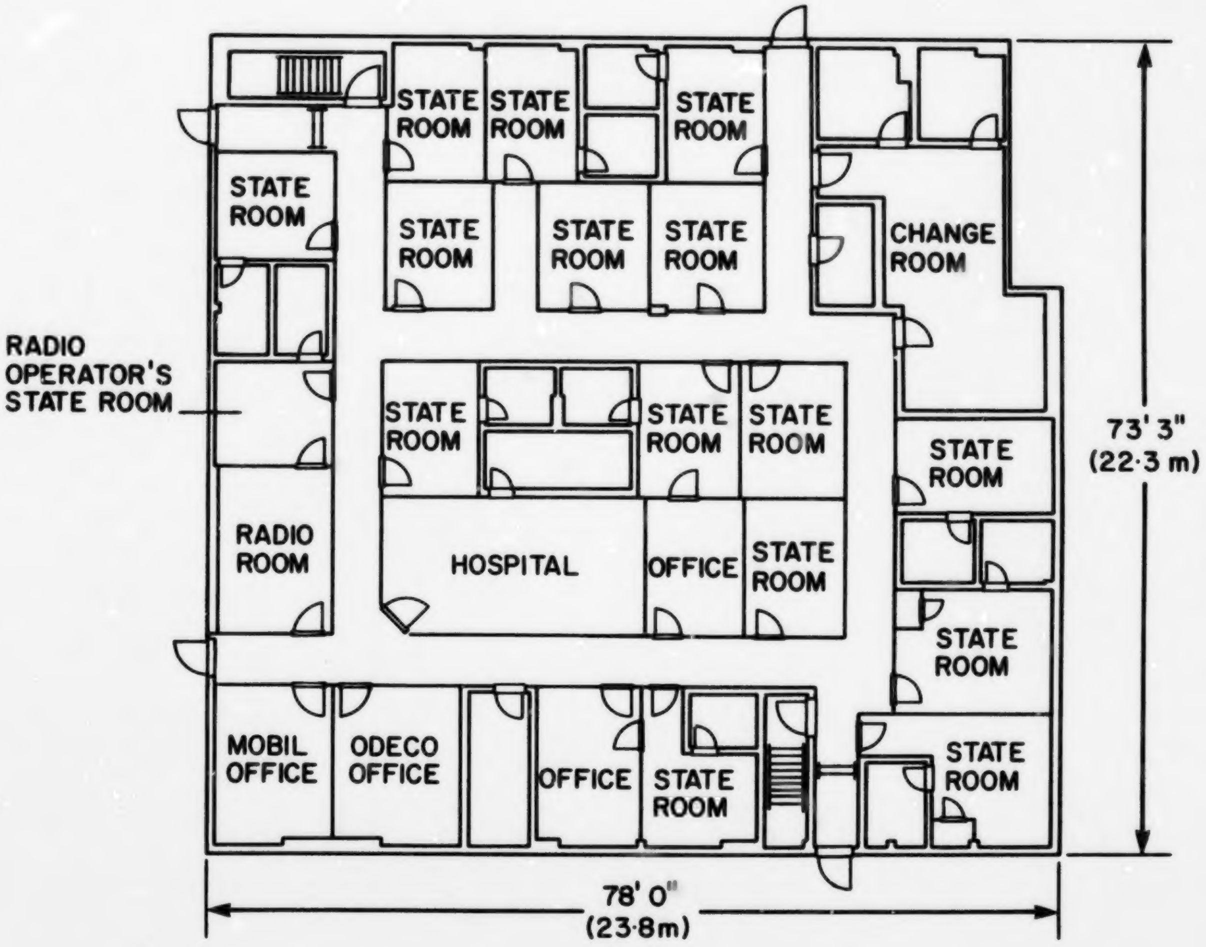
FROM G-0103 8/8

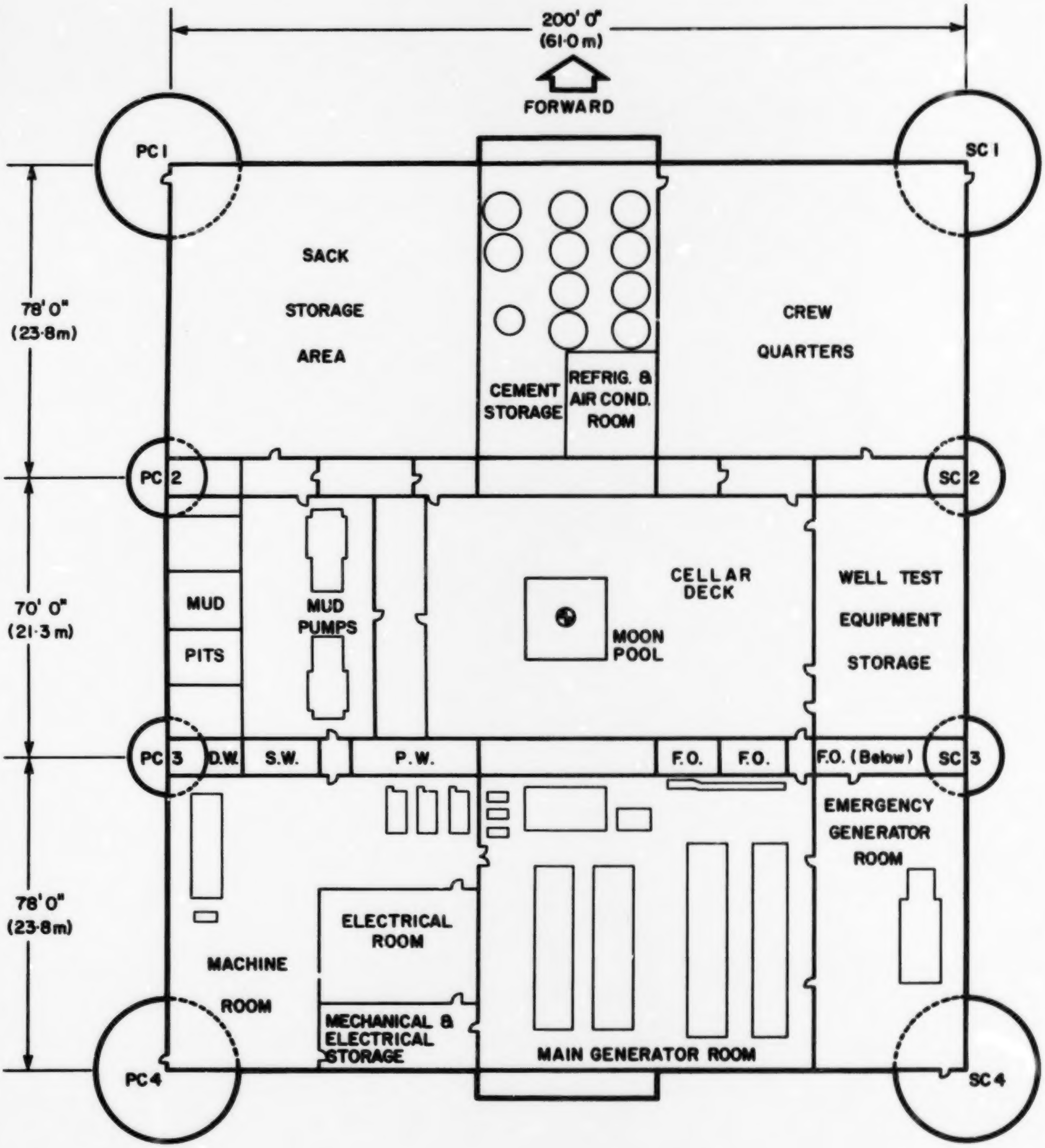

151' 5"
(46·2 m)
134' 0"
(40·8 m)
117' 1"
(35·7 m)
107' 6"
(32·8 m)
vertical ladder
63' 0"
(19·2 m)
TOP OF PONTOON
24' 0" (7·3 m)
BASELINE (KEEL)
0' 0"
LOOKING FORWARD
UPPER DECK
weathertight
hatch
LOWER DECK
watertight
manholes
spiral
staircase
WINDLASS
CONTROL ROOM
non-tight
manhole
BALLAST
CONTROL ROOM
watertight
manhole
PRESSURE TANK
COMPARTMENT
'p' tank
(above)
deck opening

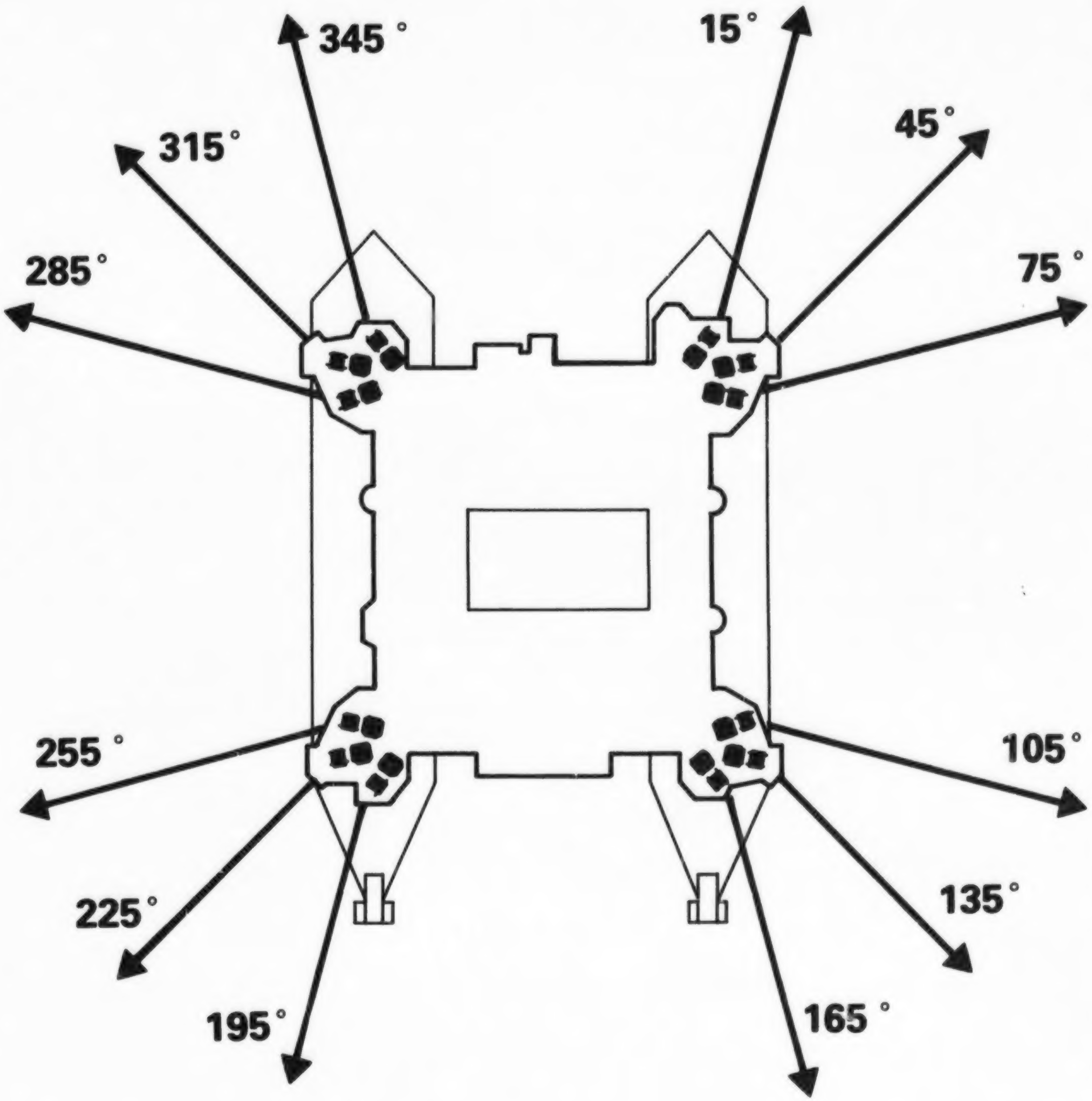
OCEAN RANGER

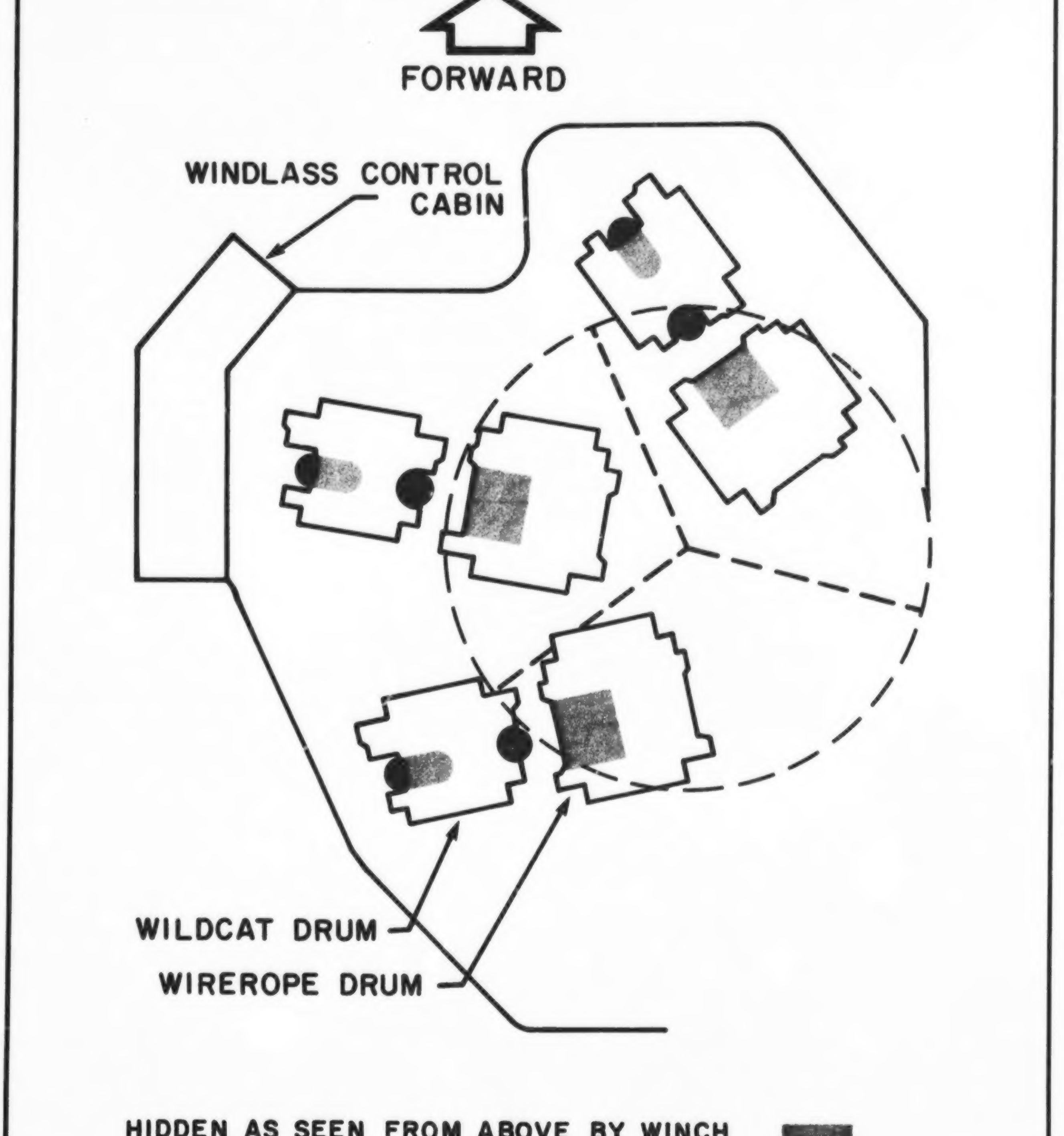
GENERAL ARRANGEMENT OF QUARTERS THIRD FLOOR

ELEV. 155' 0" (47·2 m)


STATE ROOM
STATE ROOM
STATE ROOM
STATE ROOM
STATE ROOM
STATE ROOM
STATE ROOM
CHANGE ROOM
RADIO OPERATOR'S STATE ROOM
STATE ROOM
STATE ROOM
STATE ROOM
STATE ROOM
RADIO ROOM
HOSPITAL
OFFICE
STATE ROOM
STATE ROOM
MOBIL OFFICE
ODECO OFFICE
OFFICE
STATE ROOM
STATE ROOM
73' 3" (22·3 m)
78' 0" (23·8m)


200' 0"
(61·0 m)
FORWARD
PC 1
SC 1
SACK STORAGE AREA
CEMENT STORAGE
REFRIG. & AIR COND. ROOM
CREW QUARTERS
78' 0"
(23·8m)
PC 2
SC 2
MUD PITS
MUD PUMPS
CELLAR DECK
MOON POOL
WELL TEST EQUIPMENT STORAGE
70' 0"
(21·3 m)
PC 3
D.W.
S.W.
P.W.
F.O.
F.O.
F.O. (Below)
SC 3
EMERGENCY GENERATOR ROOM
ELECTRICAL ROOM
MACHINE ROOM
MECHANICAL & ELECTRICAL STORAGE
MAIN GENERATOR ROOM
78' 0"
(23·8m)
PC 4
SC 4


345°
15°
315°
45°
285°
75°
255°
105°
225°
135°
195°
165°


FORWARD
WINDLASS CONTROL CABIN
WILDCAT DRUM
WIREROPE DRUM
HIDDEN AS SEEN FROM ABOVE BY WINCH OR DRUM
OPEN AS SEEN FROM ABOVE

THE CASUALTY

APPENDIX G

APPENDIX G

THE CASUALTY

1. DISTRESS TELEX 377
Transmitted from the *Ocean Ranger* at 0439 Zulu (1:09 a.m. NST) February 15, 1982, to the United States Coast Guard Rescue Coordination Center, New York.
Exhibit #66.

2. LIST OF CREW MEMBERS RECOVERED BY DATE, TIME AND LOCATION 378
Compiled from Royal Canadian Mounted Police information.
Exhibit #200.

3. LIST OF *OCEAN RANGER* CREW MEMBERS RECOVERED. 379
Extract from Exhibit #41.

4. LIST OF *OCEAN RANGER* CREW MEMBERS NOT RECOVERED. 380
Extract from Exhibit #41.

5. ITEMS RECOVERED DURING SEARCH AND RESCUE OPERATIONS 383
February 15 to February 25, 1982.
Extract from internal RCMP Report.

6. TABLE: AIRCRAFT NON-AVAILABILITY THROUGH MAINTENANCE ACTION 385
103 Rescue Unit, Canadian Forces Station Gander.
Extract from Exhibit #193.

NOTE: The call connection between the *Ocean Ranger* and the CG RCC New York was broken at 0500Z. Thirteen attempts were made to regain contact between 0500 – 0626Z, but were unsuccessful.

Item G-1
Distress Telex Transmitted from the *Ocean Ranger* at 0439 Zulu (1:09 a.m. NST) February 15, 1982

(2/15/82)

HQT 0439Z

CENB 1330702

ARE EXPERIENCING A SEVERE LIST U NABLE TO CORRECT PROBLEM. NOTIFYING YOU PF PROBLEM QSL

(TELEX SWITCH OPTR-COMSAT) DO YOU WISH CONNECTION TO COAST GUARD AND WHAT SATELLITE ARE YOU ON GA

(O.C.) R R I WUD WISH CONN AM ON SATELLITE

(TELEX SWITCH) DO U WISH COAST GUARD NYK OR SAN FRANCISCO GA

(O.C.) NYK PLS

(TLEX SWITCH) MOM
230127775+ CONNECTION MADE WITH USCG RCC NYK 0442.6Z 15 FEBRUARY

USCG RCC NYK
USCG RCC NYK

CENB 1330702

(O.C.) WE ARE THE ODECO OCEAN RANGER KRTB LOC 46.43.33 N 48.50.13W AND ARE EXPERIENCING A SEVERE LIST OF ABOUT 10-15 DEGREES AND ARE IN THE MIDDLE OF A SEVERE STORM AT THE TIME 12 DEGREES AND PREGRESSING..REQUEST ASST ASAP..WE ARE AN OFFSHORE DRILLING PLATFORM..
GA

(C.G.) DE RCC NYK WILL PASS INFO
(O.C.) R R WE WILL STBY AS LONG AS POSS
CENB 1330702
(O.C.) WINDS AT THIS TIME ARE APPROX FROM THE WEST AT APPROX 75 KNOTS.
RIG IS OF SEMI-SU SUBMERSIBLE BUILD AND IS LISTING SEVERELY
12-15 DEGREES TO THE PORT SIDE.. GENL INFO
CENB 1330702

(C.G.) USCG RCC NYK
INFO HAEEE
INFO IS BEING FOREWARDED TO RCCHALEEE RCC HALIFAX
GA
(O.C.) R RGA
(O.C.) R R WE CHECK THAT ALL AVAILABLE WORKBOATS IN THE IMMEDIATE AREA ARE COMING TO OUR ASST THERE ARE TWO OTHER SEMI SUBMERSIBLES IN THE AREA AND WILL DO ALL POSSIBLE TO ASSIST

GA
(C.G.) R R WILL ALSO PASS THIS INFO

Item G-2
List of Crew Members Recovered by Date, Time and Location

NAME	RECOVERED BY	LOCATION	TIME (LOCAL)
Melvin Freid	*Nordertor*	46°35'N/48°31.5'W	1150, Feb. 15, 1982
Craig Tilley	*Schnoorturm*	46°30'N/48°37'W	1645, Feb. 16, 1982
Kenneth O'Brien	*Hudson*	These five (5) bodies were recovered at the following times and locations. The recovery time and locations sequence does not necessarily correspond. 46°27.5'N/48°22.2'W, 46°27.5'N/48°19.0'W, 46°27.5'N/48°17.9'W, 46°27.0'N/48°19.0'W, 46°27.6'N/48°18.9'W,	0917, Feb. 17, 1982 1034, Feb. 17, 1982 1100, Feb. 17, 1982 1145, Feb. 17, 1982 1145, Feb. 17, 1982
Kenneth Blackmore	*Hudson*		
Ronald Foley	*Hudson*		
Norman Dawe	*Hudson*		
Derek Escott	*Hudson*		
Thomas Blevins	*Java Seal*	Nine (9) of the bodies recovered by the *Java Seal* were recovered on Feb. 17, 1982 between 0855 and 1050 within a three mile radius of 46°27.8'N/48°21.4'W Three (3) of the bodies recovered by the *Java Seal* were recovered on Feb. 17, 1982 at 1300 at 46°25'N/48°11'W One (1) of the bodies recovered by the *Java Seal* was recovered at 0815 on Feb. 18, 1982 at 46°19.1'N/48°13'W	
Wade Brinston	*Java Seal*		
Wayne Miller	*Java Seal*		
George F. Augot	*Java Seal*		
Ron E. Heffernan	*Java Seal*		
Robert Hicks	*Java Seal*		
Joseph C. Burry	*Java Seal*		
Cliff Kuhl	*Java Seal*		
Douglas Putt	*Java Seal*		
Woodrow Warford	*Java Seal*		
Robert Wilson	*Java Seal*		
William David Smith	*Java Seal*		
David Leon Droddy	*Java Seal*		
Gerald Clarke	*Boltentor*	45°41.5N/48°28'W	1215, Feb. 20, 1982
Kenneth Chafe	*Bartlett*	45°43'N/48°23'W	0825, Feb. 20, 1982

Item G-3
List of Ocean Ranger Crew Members Recovered

COMPANY	NAME	ADDRESS
ANALYSTS OF CANADA LTD.	ESCOTT, Derek Logging Engineer	Mount Pearl, NF
ATLANTIC FORTIER	WARFORD, Woodrow Steward	Carbonear, NF
EASTEEL INDUSTRIES	CHAFE, Kenneth Fitter	Topsail, NF
	CLARKE, Gerald Welder	St. John's, NF
	PUTT, Douglas Welder	Goulds, NF
HYDROSPACE MARINE SERVICES	MILLER, Wayne Diver	St. John's, NF
NEYTFOR (TURBO-DRILL)	KUHL, Cliff	Brooks, AB
	WILSON, Robert	Calgary, AB
ODECO DRILLING	AUGOT, George F. Floorman	Torbay, NF
	BLACKMORE, Kenneth Medic	Norris Arm, NF
	BLEVINS, Thomas Derrickman	Plainfield, CT, USA
	BRINSTON, Wade Crane Operator	Arnold's Cove, NF
	BURRY, Joseph C. Welder	Norman's Cove, NF
	DAWE, Norman Motorman	Harbour Grace, NF
	DRODDY, David Leon Driller	Covington, LA, USA
	FOLEY, Ronald Roustabout	St. John's, NF
	FREID, Melvin Materials	St. John's, NF
	HEFFERNAN, Ron E. Roustabout	St. John's, NF
	HICKS, Robert L. Mech/Elect. Supervisor	Goose Creek, SC, USA
	O'BRIEN, Kenneth Floorman	St. John's, NF
	SMITH, William David Rig Mechanic	Valley Station, KY, USA
	TILLEY, Craig Roustabout	St. John's, NF

Item G-4
List of Crew Members Not Recovered and Presumed Dead

ANALYSTS OF CANADA LTD.	DODD, Jim Senior Logging Engineer	Berwick, NS
	FOGG, Peter Total Concept Unit Manager	Mount Pearl, NF
	GREENE, Cyril Sample Catcher	Piccadilly, NF
	HOLDEN, Derek Senior Logging Engineer	Mount Pearl, NF
	SHEPPARD, Rick Logging Technician	St. John's, NF
	SMIT, Frank Logging Technician	Kilbride, NF
ATLANTIC FORTIER	CONWAY, Daniel Steward	St. John's, NF
	DWYER, Terrance Chief Steward	Carbonear, NF
	HARNUM, Fred Steward	St. John's, NF
	NOSEWORTHY, Randy Night Cook	St. John's, NF
	PINHORN, John Steward	St. John's, NF
	RYANN, Dennis Steward	Medford, ON
	SMITH, William Steward	St. John's, NF
BAROID OF CANADA LTD.	HOWLAND, Robert C.	Calgary, AB
D'EON, MILLER & ASSOC.	HATFIELD, Tom Geologist	Wolfville, NS
DOWELL OF CANADA LTD.	DAGG, Arthur Cementer	St. John's, NF
HYDROSPACE MARINE SERVICES	CRAWFORD, Gary Diving Supervisor	St. John's, NF
	HALLIDAY, Norman Diver	Toronto, ON
	MITCHELL, Gord Diver	Lacombe, AB
	MORRISON, Perry Diver	Weston, ON
MacLAREN PLANSEARCH LTD.	CAINES, Greg Ice & Weather Observer	St. John's, NF
	DRAKE, Wayne Ice & Weather Observer	Kilbride, NF

PORTA TEST SYSTEMS LTD.	ARSENAULT, Robert Field Supervisor	St. John's, NF
	REID, Darryl Field Operator	Upper Gullies, NF
	TILLER, Greg Field Operator	Mount Pearl, NF
SCHLUMBERGER OF CANADA	CHALMERS, David Sr. Field Engineer	St. John's, NF
	HOWELL, Robert Sr. Wireline Operator	London, ON
MOBIL OIL CANADA LTD.	FENEZ, Robert Drilling Engineer	St. John's, NF
	JACOBSEN, Jack Drilling Foreman	Tusket, NS
	MADDEN, Robert Drilling Foreman	Calgary, AB
ODECO DRILLING	BALDWIN, Nicholas Floorman	Carbonear, NF
	BOUTCHER, David Floorman	Corner Brook, NF
	BURSEY, Paul Electrician	St. John's, NF
	DONLON, Thomas Electrician	Sumter, SC, USA
	DUGAS, William Crane Operator	Abbeville, LA, USA
	DYKE, Domenic Control Room Operator	Eastport, NF
	EVOY, Andrew Roustabout	Mount Carmel, NF
	FERGUSON, Randell Subsea Technician	Natchez, MS, USA
	FRY, Carl Mud Watcher	St. John's, NF
	GANDY, George Rig Mechanic	Logansport, LA, USA
	GERBEAU, Guy Derrickman	Montreal, PQ
	GORUM, Reginald Driller	El Paso, TX, USA
	HAUSS, Capt. Clarence Barge Master	Baltimore, MD, USA
	HICKEY, Gregory Radio Operator	Torbay, NF
	HOWELL, Albert Motorman	Mount Pearl, NF

ODECO DRILLING	LEDREW, Harold Roustabout	Botwood, NF
	LEDREW, Robert Floorman	Botwood, NF
	MAURICE, Michael Roustabout	St. John's, NF
	MELENDY, Ralph Floorman	St. John's, NF
	O'NEILL, Paschal Joseph Roustabout	Fermeuse, NF
	PALMER, George Roustabout	St. John's, NF
	PARSONS, Clyde Floorman	Foxtrap, NF
	PIEROWAY, Donald Roustabout	Barachois Brook, NF
	POWELL, Willie Assistant Toolpusher	Franklinton, LA, USA
	POWER, Gerald Mud Watcher	St. John's, NF
	RATHBUN, Donald Control Room Operator	Narragansett, RI, USA
	STAPLETON, Ted Electronic Technician	Mount Pearl, NF
	THOMPSON, B. Kent Toolpusher	Hattiesburg, MS, USA
	VAUGHN, Gerald Assistant Toolpusher	Collins, MS, USA
	WATKINS, Michael Industrial Relations Representative	New Orleans, LA, USA
	WINDSOR, Robert Floorman	Paradise, NF
	WINDSOR, Stephen Roustabout	Paradise, NF

Item G-5
Items Recovered During Search and Rescue Operations

This will cover receipt and identification of exhibits received at Pier 17, St. John's Harbour, by ship from the *Ocean Ranger* Marine Disaster. The larger exhibits are stored in Building 205, Pleasantville, St. John's, Newfoundland. The remainder of exhibits are stored at the R.C.M. Police Office, Donovans, Newfoundland.[1]

At 0720 hours, 82 FEB 17, the supply vessel *Nordertor*, under Captain Baxter ALLINGHAM, arrived at Pier 17. The following exhibits were received:

1. One bronze propellor attached to a four foot length of drive shaft. Propellor and shaft were torn from an *Ocean Ranger* lifeboat as the *Nordertor's* crew were trying to pull the lifeboat on its own deck. This occurred on 82 FEB 15 at 1150 hours (local time). Position was 46°35'N and 48°31'5"W. This information is from the ship's log.

2. One 58-man orange lifeboat marked *Ocean Ranger* #3. Lifeboat was manufactured by Watercraft America Inc. and its serial number is ELZ8-034/11/79. The lifeboat was noted to be upside down on the deck of the *Nordertor* and secured with cables and chains. One cable had sliced through halfway of the hull of the lifeboat. The upper structure was completely destroyed and the boat was not provisioned but did carry two oars marked *Ocean Ranger*. Lifeboat was picked up on 82 FEB 16 at 1220 hours at position 46°24'N/48°15'W.

At 1540 hours, 82 FEB 19, the supply vessel *Ravensturm* arrived at Pier 17 and the following five exhibits were received from First Mate, John COONEY:

3. The bottom section of an Elliot 20-man rubber life raft in poor condition. Raft picked up on 82 FEB 17 at 1454 hours and the position was 46°14'N/47°24.2'W.

4. The top section of an Elliot 20-man rubber life raft. The canopy was noted to be badly torn and the rubber sections of the raft to be separating from one another. No air in any of the raft sections. Raft picked up on 82 FEB 17 at 1454 hours and the position was 46°14'N/47°24'W.

5. One grey ten gallon can with large dent in side and considerable amount of rust on same. Can picked up on 82 FEB 17 at 1500 hours, position was 46°14'N/47°24'W.

6. One large piece of yellow styrofoam, similar to the foam used in Lifeboat #3 off the *Ocean Ranger* but not from Lifeboat #3. This foam was picked up on 82 FEB 17 at 1500 hours at position 46°14'N/47°24'W.

7. Same as (6) above.

At 0613 hours, 82 FEB 20, the *MV Java Seal*, under Captain Robert FRONTIERRO, was boarded and the following items obtained:

8. Thirteen BILLY PUGH lifejackets.

9. One BILLY PUGH work vest and an assortment of other flotsam.

10. One garbage bag containing a coil of orange rope, one illumination marker, and nine cans of drinking water. These items are similar to the supplies found in an Elliot 20-man rubber life raft. These items were picked up on 82 FEB 18, at 1250 hours, at position 46°13'N/47°49'W.

11. One fluorescent orange supply bag from an Elliot 20-man life raft containing forty cans of drinking water. This bag was picked up on 82 FEB 18 at 1430 hours. Position was 46°07'N/47°41'W.

At 1010 hours, 82 FEB 22, the supply vessel *Boltentor*, under Captain J.C. DAVISON, arrived at Pier 22 and the following exhibits were obtained:

12. One *Ocean Ranger* 50-man HARDING lifeboat. Lifeboat was manufactured in 1974 at Bjorke Batbyggeri, Rosendal, Norway. Serial #2978. This lifeboat was fully provisioned but in poor condition. Two portable marine radios inside the lifeboat were marked *Ocean Ranger* No. 1. Noted lifeboat to have most of the upper structure attached but crushed down onto the boat. The bow section of the boat was split open and the front davit was missing. Boat picked up on 82 FEB 16 at 1310 hours (local time) at position 46°16'N/48°08'W.

13. One section of a BILLY PUGH work vest. No markings on vest. Vest picked up on 82 FEB 17 at 1320 hours and the position was 46°1'N/47°11'W.

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[1] An extract from an internal RCMP Report on the items removed from the vessels involved in the Search and Rescue effort.

14. One fluorescent orange bag from an Elliot 20-man life raft containing 24 cans of drinking water. Bag was picked up on 82 FEB 17 at 1320 hours and the position was 46° 1'N/47° 12'W.

15. One Elliot 20-man rubber life raft. Raft was in fair condition with several sections of the bottom inflated but the top canopy was badly torn. Raft picked up on 82 FEB 17 at 1325 hours (local time) and the position was 46°01'N/47°11'W.

At 1055 hours, 82 FEB 23, the supply vessel *Seaforth Highlander*, under Captain Ronald Stewart DUNCAN, was boarded and the following exhibits obtained:

16. One Elliot 20-man rubber life raft in poor condition. Raft was torn apart and fully deflated. Canopy was mostly missing and what was left was in shreds. Raft picked up on 82 FEB 17 at 1255 hours. Position was 45°47'N/46°41'W.

17. One fluorescent orange bag containing sixteen cans of drinking water and two red hand flares. Flares were in plastic bag but waterlogged. Same was picked up on 82 FEB 17 at 1422 hours and the position was 45°49'N/46°39.5'W.

18. One ball of heavy yellow rope. Rope was picked up on 82 FEB 17 at 1652 hours. Position was 46° 10'44"N and 48° 11'31"W.

At 1100 hours, 82 FEB 25, the Canadian Coast Guard Ship *Bartlett*, under Captain Phillip GRANDY, was boarded and the following exhibits obtained:

19. One Elliott 20-man rubber life raft in two sections. Raft was deflated and torn up badly. Canopy was shredded and mostly missing. Raft was picked up on 82 FEB 20 at 0620 hours (local time) and the position was 45°47'N/48°22.6'W.

20. One BILLY PUGH lifejacket removed from the body of an *Ocean Ranger* victim. Lifejacket was marked *Ocean Ranger*. This lifejacket was recovered on 82 FEB 20 at 0825 hours (local time) and the position was 45°43'N/48°23'W.

21. One E.L.T. (Emergency Locator Transmitter) marked *Ocean Ranger*. This E.L.T. was still operating when picked up on 82 FEB 20 at 1407 hours at position 45°47'N/48°22.6'W.

22. One grey fibreglass centre section from a lifeboat. This section was full of provisions and had a checkoff sheet marked Lifeboat No. 2. It was picked up on 82 FEB 20 at 0620 hours (local time) at position 45°43'N/48°23'W.

In addition to the preceding items, the following have since been discovered:

a. On 83 JUL 12, a Fishery Products trawler, the *Zambezi* recovered one Elliott 20-man rubber life raft at position 45°30'N/48°50'W while fishing off the Grand Banks; the vessel docked in Catalina and the life raft was turned over to the RCMP.

b. Two life vests marked *Ocean Ranger* washed ashore at the Faroe Islands, just North of Scotland. They were recovered separately during the summer of 1982.

Item G-6
Aircraft Non-availability Through Maintenance Action

HELICOPTER 301	HELICOPTER 302	HELICOPTER 310
DATES/TIME LENGTH 1981	DATES/TIME LENGTH 1981	DATES/TIME LENGTH 1981
12 Mar – 14 Apr (34 days)	16 Mar – 16 Mar (7 hrs)	11 Mar – 17 Mar (6 days)
15 Apr – 16 Apr (1 day)	22 Mar – 26 Mar (14 hrs)	23 Mar – 01 Apr (8 days)
25 Apr – 25 Apr (8 hrs)	27 Mar – 27 Mar (16.5 hrs)	07 May – 08 May (24 hrs)
30 Apr – 06 May (6 days)	02 Apr – 02 Apr (10 hrs)	14 May – 14 May (7 hrs)
10 Jun – 12 Jun (2 days)	06 Apr – 06 Apr (9 hrs)	15 May – 17 May (2 days)
18 Jun – 19 Jun (19 hrs)	10 Apr – 10 Apr (4 hrs)	19 May – 02 Jun (13.5 days)
20 Jun – 21 Jun (33 hrs)	15 Apr – 15 Apr (13 hrs)	04 Jun – 04 Jun (5 hrs)
03 Jul – 03 Jul (3.5 hrs)	21 Apr – 23 Apr (58 hrs)	15 Jun – 15 Jun (6 hrs)
07 Jul – 09 Jul (46 hrs)	28 Apr – 01 May (2.5 days)	18 Jun – 19 Jun (16 hrs)
21 Jul – 09 Sep (51 days)	17 May – 19 May (2 days)	19 Jun – 19 Jun (6 hrs)
23 Sep – 23 Sep (7 hrs)	01 Jun – 26 Jun (26 days)	29 Jun – 06 Jul (7 days)
22 Oct – 22 Oct (3 hrs)	08 Jul – 20 Jul (13 days)	11 Jul – 20 Jul (9 days)
10 Nov – 10 Nov (4.5 hrs)	27 Jul – 27 Jul (15 hrs)	31 Aug – 06 Oct (36 days)
25 Nov – 30 Nov (5 days)	06 Aug – 06 Aug (6 hrs)	08 Oct – 13 Oct (5.5 days)
14 Dec – 15 Dec (29 hrs)	12 Aug – 13 Aug (12 hrs)	16 Oct – 18 Oct (2.5 days)
	14 Aug – 14 Aug (20 hrs)	20 Oct – 21 Oct (17 hrs)
	03 Sep – 03 Sep (3.5 hrs)	02 Nov – 05 Nov (3 days)
	08 Sep – 09 Sep (8.5 hrs)	07 Nov – 09 Nov (2.5 days)
	16 Sep – 18 Sep (2 days)	04 Dec – 06 Dec (2.5 days)
	22 Sep – 23 Sep (12 hrs)	
	23 Sep – 29 Sep (6 days)	
	03 Oct – 06 Oct (4 days)	
	08 Oct – 27 Nov (51 days)	
	06 Dec – 10 Dec (4.5 days)	
	11 Dec – 11 Dec (9 hrs)	
	15 Dec – 24 Dec (8.5 days)	
DATES/TIME LENGTH 1982	DATES/TIME LENGTH 1982	DATES/TIME LENGTH 1982
22 Dec – 14 Feb (53 days)	06 Jan – 06 Jan (8 hrs)	14 Jan – 21 Jan (7.5 days)
04 Mar – 05 Mar (28 hrs)	12 Jan – 12 Jan (7 hrs)	08 Feb – 10 Feb (2 days)
05 Mar – 06 Mar (35.5 hrs)	14 Jan – 14 Jan (3.5 hrs)	22 Feb – 25 Mar (32 days)
09 Mar – 09 Mar (3 hrs)	26 Jan – 26 Jan (7 hrs)	
17 Mar – 17 Mar (2.5 hrs)	27 Jan – 27 Jan (9.5 hrs)	
	28 Jan – 28 Jan (4 hrs)	
	04 Feb – 06 Feb (2.5 days)	
	11 Feb – 11 Feb (7 hrs)	
	12 Feb – 13 Feb (1.5 days)	
	02 Mar – 31 Mar (30 days)	

GLOSSARY

GLOSSARY

ABS American Bureau of Shipping

Actuator see valve actuator

AES Atmospheric Environment Service (Canada)

Air Gap The distance between mean sea level and the underside of the lower deck of a semisubmersible.

Alert The first stage of a search and rescue incident, when a Rescue Co-ordination Centre (RCC) calls Squadron Operations to advise of incident status. RCC gives instructions to either commence take-off procedure or await further information.

All Ships Broadcast A radio broadcast made by a station to all ships within its range. Depending on the urgency involved, the all ships broadcast is prefaced by an internationally accepted term, such as the repetition of "Mayday Relay" three times for a relayed distress call.

Ammeter An instrument for measuring electrical current.

Anchor Bolster A protective rail attached to the side of a vessel or offshore structure to safeguard the structure from damage when the anchors are raised or lowered. Anchor bolsters may be seen on the pontoons or stabilizing columns of semisubmersible drilling units.

Anchor Tension The force exerted on an anchor and its mooring line by rig movement. Anchor tensions are measured in KIPS, with 1 KIP equal to 1000 pounds.

Anchor Windlass A winch used for hauling in and deploying anchor cables or chains.

Anemometer An instrument for measuring wind speed.

ASE Aviation Safety Engineering Facility, Transport Canada

Attitude The inclination of a vessel relative to true vertical.

Aurora A military fixed-wing aircraft equipped with sophisticated tracking and detection systems; military aircraft may be tasked by Search and Rescue to co-ordinate aircraft and vessel movement at the site of a marine emergency.

Authority to Drill a Well A permit issued by COGLA to an operator after a review of the detailed engineering program for a proposed well. An operator is required to obtain separate approval for each well to be drilled.

Automatic Flight Control System An aircraft navigation system which automatically maintains direction, speed, and altitude.

Ballast Control Console Located in the ballast control room of a semisubmersible, this console is equipped with controls for pumps and valves used to transfer ballast and liquid cargo to and from the tanks in the pontoons. It includes gauges and indicators used to monitor these operations.

Ballast Control Operator The person designated to operate the ballast system of a semisubmersible. Sometimes referred to as the watchstander.

Ballast Control Room The area of a semisubmersible which houses the equipment used to monitor and control the distribution of ballast. Also referred to as the barge control room.

Ballast System A system of tanks and pumps, interconnected by a network of pipes and valves; on a semisubmersible, the system is used to control draft, attitude and stability. During drilling operations, the system is routinely used to compensate for the movement and loading of equipment and supplies.

Bilge Any space in the lower part of a hull or pontoon where water collects.

Blowout A sudden, violent, uncontrolled escape of gas/water/oil, with mud, at high pressure from a well. A blowout occurs when the formation pressure exceeds the hydrostatic head of the drilling mud.

Blowout Preventer (BOP) Equipment installed on a wellhead enabling any flow from the well to be controlled by the driller, preventing excessive downhole pressure from reaching the top of the hole where it may endanger personnel and equipment.

Boat Hook An iron hook with a straight prong at its hind part, fixed to a long pole.

Booklet of Operating Conditions A book of instructions designed to assist the crew in operating the rig under normal and emergency conditions. Also referred to as the operating manual.

BOP blowout preventer.

Bow Thruster A fixed propeller mounted in a recess or tunnel in the bow of a vessel, which greatly improves manoeuvrability.

Brass Rod See Manual Control Rod.

Buffalo A fixed-wing Search and Rescue aircraft, used primarily for search, tracking and communications support.

Bulkhead Any vertical partition which subdivides the interior of a vessel into compartments or rooms.

Bulwark The raised side of a vessel above the weather deck.

Casing Very tough, thick-walled steel pipe of varying diameters which is placed inside the well as a lining to secure the hole and prevent the walls from collapsing.

CCG Canadian Coast Guard

CCGS Canadian Coast Guard Ship

CFB Canadian Forces Base

CFR Code of Federal Regulations (U.S.)

Chain Locker A compartment located under an anchor windlass in which the anchor chains are stowed.

Chain Pipe A longitudinal bulkhead pipe fitted directly under the anchor windlass to lead the anchor chains to the chain locker.

Charter Party A contractual agreement between a vessel owner and an operator.

Chinook A twin-rotor helicopter, similar in design to the Labrador/Voyageur helicopter used by Search and Rescue.

Classification Society An independent organization whose purpose is to supervise the construction, upkeep and alteration of vessels according to the society's rules for classing each particular type of vessel. Although not compulsory by law, construction of a vessel according to the rules of a society makes it much easier for the owner or charterer to secure satisfactory insurance rates.

Close Standby The condition of a standby vessel when in close proximity to a drilling unit, such as during helicopter operations and emergencies.

Coastal State A state exerting regulatory control over vessels operating within its jurisdictional limits.

COGLA Canada Oil and Gas Lands Administration

Compensator Hoses A bundle of flexible hydraulic and/or pneumatic hoses connected between the derrick and the drill string motion compensator, so as to allow the free movement of the compensator and the travelling block.

Contingency Plan A detailed plan submitted to a regulatory authority, outlining a drilling company's procedures for dealing with emergencies. The plan sets down procedures for events ranging from personal injuries to blowouts.

Damage Stability The reserve stability of a vessel in a prescribed damage condition; one of the criteria used in the classification process.

Davit A small crane located at the edge of a deck, used for lowering lifeboats and davit-launched life rafts.

Deadlight An interior metal cover affixed to a porthole which, when closed, prevents sea water ingress in the event of portlight breakage.

Deadweight Check See Reinclining Test.

Deballast To remove ballast from tanks by pumping, in order to alter the draft of a vessel.

Deckload The equipment and supplies stored temporarily on a semisubmersible.

Derrick A steel tower rising several hundred feet above the drill floor and supporting the hoisting equipment used to lower and raise the drill string.

Disconnect The process of unlatching the marine riser from the blowout preventer so that the rig is no longer physically connected to the seabed.

DND Department of National Defence (Canada)

DnV Det norske Veritas (Norway)

Dodging Pattern A term used to describe the course often followed by standby vessels during heavy weather. The vessel proceeds into the wind, at the lowest possible speed to maintain steerage. At the extreme range, the vessel executes a 180 degree turn and then proceeds downwind to turn again.

Downflooding The unintentional entry of water into a compartment. The "first point of downflooding" is the lowest opening through which water can enter the internal structure of a vessel, while the "angle of downflooding" specifies the inclination at which downflooding first occurs.

Downwind In the direction in which the wind is blowing.

Draft The depth of the keel from the surface of the water. The draft of a semisubmersible drilling unit is controlled by taking on or discharging ballast water.

Draft Marks The external marks on the hull of a vessel or the columns of a semisubmersible used to measure the draft.

Drift Plot A graphic representation of the direction and speed of an object drifting on the ocean surface, based upon a mathematical calculation involving surface current, wind and the physical configuration of the object.

Drill Bit The cutting tool attached to the lower end of the drill string. A hole in the centre of the drill bit permits drilling fluid to be pumped down through the drill pipe to circulate cuttings to the surface and to cool and lubricate the bit.

Drill Floor The working area on a drilling unit located directly above the moonpool, from which the drilling operation is carried out.

Drill Pipe Sections of hollow steel pipe 30 feet long which, when connected by threaded joints, make up the drill string.

Drill Rig In offshore exploration terminology, a fixed or mobile platform equipped to carry out a drilling operation.

Drill String An assembly of drill pipe lowered into the well. The drill bit is attached to the lower end of the string; the upper end of the string passes through the rotary table and is supported by the travelling block.

Drill Water Fresh water used in the preparation of drilling mud.

Drilling Contractor A company which is hired to drill a well on behalf of an operator.

Drilling Mode see Industrial Mode

Drilling Mud A water or oil-based fluid pumped down the drill string in order to lubricate and cool the drill bit, and to circulate cuttings back to the surface through the marine riser. The weight of the mud prevents the uncontrolled entry of formation fluids into the well and helps to prevent the sides of the open hole from collapsing. The weight and chemical properties of the mud are varied regularly in response to downhole conditions.

Drilling Program A program for the drilling of one or more wells within a specified area and time using one or more drilling units and including all ancillary operations and activities. Approval for a drilling program is granted to an operator upon provision of detailed information on the exploration program including extensive documentation on the purpose, location, timing, nature and logistics of the program. Geological and environmental data, information on rigs to be used, and a detailed contingency plan for emergencies must also be provided to the regulatory authority issuing approval.

Emergency Communications Officer Identified in Mobil's Contingency Plan as the Mobil representative who, during an emergency or disaster, has control over emergency procedures and the transmission of information. This position is normally filled by one of the following: Drilling Superintendent, Drilling Supervisor, Engineering Supervisor, Logistics Supervisor or Accounting Supervisor.

EMR Energy, Mines and Resources (Canada)

Fail-safe Describes a mechanism or system which incorporates an element that enables it to return automatically to a safe condition in the event of a breakdown or malfunction.

Fairlead A ring bolt, eye or pulley which guides a rope or chain in a required direction; often one element of a mooring system.

Flag State The country in which a vessel is registered.

Freeboard The distance measured on a vessel's side from the water-line to the upper surface of the uppermost continuous deck having permanent means of closing all weather openings.

Gas Detection System Detects the presence of combustible or noxious gas. Gas detectors are installed around the drill floor, in mud rooms, shaleshaker rooms, and in intake and exhaust ports to all pressurized areas of an offshore installation.

GM See Metacentric Height.

GMT Greenwich Mean Time. See (Z) (Zulu time).

Grappling Hook An implement with two or more hooks radiating from a common shank attached to a rope, used for anchoring small boats and recovering objects. Also called a Grapnel.

Gunwale The side of a vessel above the waterline up to the weather deck.

Gust Spread Refering to wind velocity, gust spread is the difference between the measured sustained wind and gusting wind velocity.

Hang-off The process of suspending the drill string from the pipe rams in the blowout preventer. Hanging-off allows the rig to disconnect from the BOP without having to remove the entire drill string from the well.

Heave The total vertical movement of a vessel relative to the seabed. Heave is of great significance in the operation of floating drilling platforms, since the rig is connected to the seabed. Heave or motion compensators will protect the drilling equipment within certain specified limits.

Heel The inclination of a vessel to port or starboard.

Heeling Moment An environmental or other force which acts to move a vessel away from the upright position.

Helideck A small landing area for helicopters. Most offshore rigs and platforms are fitted with helidecks.

HF high frequency

HF Radio A radio system using the high frequency band between 3 and 30 megahertz.

Hibernia Field An area of the Grand Banks off Southeastern Newfoundland with known petroleum reserves which have been explored since 1966.

Hot Refuel The refuelling of a helicopter during severe environmental or emergency conditions which preclude the helicopter's engines from being shut down during the refuelling process.

Hover Coupler System In conjunction with an automatic flight control system, this system uses a doppler radar and allows a helicopter to maintain a hover position without assistance from the pilot.

Hydrostatic Release Mechanism An automatic device designed to release an inflatable life raft from its container should the container become submerged.

Hypothermia The condition of abnormally low body core temperature produced by exposure to cold air or water.

Immersion Suit A generic term used to describe protective clothing which offers varying degrees of insulation from cold air and water. Three types of suits are currently being used offshore: (1) helicopter suits which are used by personnel while being transferred by helicopter; (2) insulated coveralls which are used by personnel working in a cold environment; (3) survival suits which are water and windproof one-piece garments designed to give wearers maximum protection from hypothermia.

IMO International Maritime Organization

IMP Industrial Marine Products Limited

In Trim A vessel is "in trim" when the deckload and ballast are such that the vessel has zero degrees of inclination.

Inclinometer An instrument for measuring the inclination of a vessel with respect to the vertical.

Industrial Mode (Drilling Mode) The condition of a semisubmersible while drilling. The draft is adjusted to attain minimum vessel motions.

International Distress Frequency 2182 kHz The radio frequency allocated by international agreement to distress calls.

Jackscrew A threaded bolt attached to the actuator of a remotely operated valve, allowing the valve to be opened or closed manually using a wrench.

KG The distance between the heel (K) and the centre of gravity (G). KG is one of the significant variables involved in calculating the stability of a vessel.

kHz kiloHertz (frequency)

King Gauge Manufacturer's name for a vertical, mercury pressure gauge system used to determine the level of the liquids in tanks.

KIPS An abbreviation for "kilopounds", usually used in reference to anchor tensions. One KIP is equal to 1000 pounds.

Lifeboat Stations The allotted place on board a vessel for gathering the crew in preparation for evacuation by lifeboat. The duties of each person on board during an emergency are listed here also.

Lifeline A rope stretched fore and aft along a deck to give the crew safety against being washed overboard in heavy weather. Also, a rope thrown to any person who has fallen overboard.

List The inclination of a vessel in any position other than upright, i.e. a combination of heel and trim.

Load Line The waterline corresponding to the maximum draft to which a vessel is permitted to load either by regulations, conditions of classification or conditions of service.

Load Line Certificate A certificate issued by the Flag State verifying the acceptable load line of a vessel in accordance with internationally adopted criteria.

Longitudinal Running from bow to stern e.g. longitudinal girder.

Manifold The junction of several incoming lines with one or more outlets, and incorporating valves and instruments where necessary to monitor fluids flowing in individual lines.

Manual Control Rod (Brass Rod) On the *Ocean Ranger*, a small tool consisting of a threaded brass rod and threaded brass bushing, which could be used to open the solenoid valves in the ballast control console. The manual control rods enabled the manual operation of the rig's ballast valves, bypassing the electrical mimic panel.

Manual Sea Chest Valve A manually operated valve located adjacent to the sea chest in the ballast piping system. Closing the manually operated sea chest valve will prevent any ingress of sea water into the ballast system.

MARCOM Maritime Command Operations (Canada)

Marine Emergency Duties (MED) A certificate required by the Canadian Ministry of Transport for most grades of seamen and officers to ensure a minimum level of marine survival skills. Course content includes training in lifesaving appliances, fire fighting, rescue and survival.

Marine Riser A large diameter pipe connected from the slip joint to the blowout preventer. The riser provides access to the well and a conduit for the circulation of drilling mud.

MARISAT System A satellite communication system providing voice, telex, facsimile and data transmission with global coverage for vessels and offshore installations. MARISAT uses the super high frequency band and its services can be linked into commercial telephone and data networks. A machine-logged, time record is kept of calls made on the MARISAT system.

Mayday The internationally accepted radio message transmitted by stations in distress. Derived from the French "m'aider", or "help me."

Mayday Relay A Mayday message forwarded to appropriate authorities on behalf of and at the request of the vessel in distress.

MED Marine Emergency Duties

Metacentric Height The vertical distance between the centre of gravity (G) and the transverse or longitudinal metacentre (M_T or M_L), abbreviated GM_T or GM_L. A measure of stability: a vessel is stable when its centre of gravity is below its metacentre.

Microswitch A small enclosed switch; microswitches are widely used in industrial applications involving repeated cycling, such as limit switches on motorized equipment.

Mimic Panel The portion of the ballast control console on which the layout of the pontoon tanks and piping system is represented.

Mobile Offshore Drilling Unit (MODU) A self-contained and movable platform or ship supporting a drilling system. This designation includes jack-ups, drillships, barges and semisubmersibles.

MODU Mobile Offshore Drilling Unit

Monkey Fist A heavy knot worked in at the end of a heaving line to weight it. A lead or iron weight is sometimes placed inside the knot before it is tightened.

Moonpool An opening through the hull of a semisubmersible, drillship or diving support vessel which allows equipment to be lowered to the seabed. The moonpool is normally located at the geometric centre to minimize the effects of vessel motion.

Mooring Lines A chain, cable or rope by which a vessel is secured to a dock or anchor.

Mooring Pattern An established system of setting anchors as determined by environmental factors and the requirements of a drilling program. Also, the physical position of the anchors of a vessel, as deployed at a drill site, is referred to as its mooring pattern.

Mooring System A system of ropes, wire-ropes or chains which are paid out from winches on board a vessel and attached to anchors used to secure the vessel in place.

Motion Compensator A pneumatic or hydraulic device on a floating drilling unit, which counteracts the effects of the vessel's motions on the drilling operation.

Muster List A list which identifies all crew members by job description, and details their emergency duties and the lifeboats to which they are assigned.

Nautical Mile (NM) The standard unit of measure for marine navigation; one nautical mile equals 6000 feet.

NHL Norwegian Hydrodynamic Laboratories

NORDCO Newfoundland Oceans Research and Development Corp.

NRC National Research Council of Canada

NST (Newfoundland Standard Time) A time zone which is 3½ hours earlier than Greenwich Mean Time (Zulu).

NTSB National Transportation Safety Board (U.S.)

ODECO Ocean Drilling & Exploration Company and its subsidiaries.

Offshore Employment Register A register, maintained by the Government of Newfoundland, of persons seeking employment in the offshore exploration industry.

On-Scene Commander A position assigned to an individual when a search and rescue mission will take place where communications may be a problem and on-site co-ordination is essential.

Operating Manual See Booklet of Operating Conditions.

Operator An oil company, often acting on behalf of a consortium of oil companies, that manages an offshore exploration or production program.

OSC on-scene commander

P.A. System Public address system; a means for making general announcements over a rig-wide system of loudspeakers, which may also provide a party-to-party telephone system and incorporate the general, fire and abandon ship alarms.

PEI Prince Edward Island

Phone Patch The process of electronically connecting a radio system to the public telephone system in order to allow two-way communication between a remote radio station and a telephone subscriber.

Photomicrograph A photograph taken at extremely high magnification through an optical or scanning electron microscope.

Pitch The bow/stern oscillation of a vessel.

Porthole A metal frame that contains a glass window, or portlight; portholes are fitted in the sides and superstructure of a vessel and may or may not be capable of opening.

PSI pounds per square inch

RCC Rescue Co-ordination Centre

RCMP Royal Canadian Mounted Police

RCV remotely controlled vehicle

Reinclining Test A test performed on a vessel, subsequent to the inclining test at the time of construction, if an unrecorded increase in weight is suspected. Inclining tests are administered by classification societies, and allow an accurate determination of a vessel's displacement and stability characteristics.

Remotely Controlled Vehicle (RCV) An unmanned submersible used to perform underwater tasks, such as photography, welding and the retrieval of objects, where the use of divers is impractical.

Rescue Co-ordination Centre (RCC) The place from which search and rescue efforts for a geographically defined Search and Rescue Region are co-ordinated and controlled. The Hibernia area is in the Halifax Search and Rescue Region.

Response Time The time elapsed before search and rescue resources are mobilized after an incident has been reported to a Rescue Co-ordination Centre or one of the sub-centres in its Search and Rescue Region.

Righting/Heeling Energy Ratios The relationship between those forces of weight and buoyancy which act to move a vessel towards the upright position and those which act to move the vessel away from the upright position.

Rime Icing Rime icing occurs when precipitation freezes on impact and builds up on a surface in a bumpy layer. It is opaque in color and different from freezing rain which results in a clear, smooth layer of ice.

Roll The port/starboard oscillation of a vessel.

Rotary Table The machinery fitted into the drill floor which rotates the drill string.

Rubbing Strake An external fender extending along the sides of a vessel a short distance above the waterline to protect against collision damage.

Samson Line A light, white line made out of two or three strands of hemp, usually manufactured in coils of 30 fathoms.

SAR Search and Rescue

SARCUP Search and Rescue Capability Update Program.

SAREC Search and Rescue Emergency Centre.

Scramble Net A net suspended from the side of a vessel to allow evacuation or boarding.

Sea Chest An intake in a vessel's side which permits taking on sea water for ballast or cooling.

Search and Rescue Capability Update Program (SARCUP) A Canadian Government plan undertaken to re-fit and upgrade SAR helicopters with equipment which increases their effectiveness.

Search and Rescue Emergency Centre (SAREC) A sub-centre within a Search and Rescue Region whose resources are co-ordinated by a Rescue Co-ordination Centre. Since 1983 these sub-centres have been called "Marine Rescue Sub Centres (MRSC)". St. John's SAREC is a sub-centre of RCC Halifax.

Seaworthiness The sufficiency of a vessel in materials, construction, equipment, crew and outfit for the trade or service in which it is employed. In U.S. law, a vessel is seaworthy if it is "reasonably adequate for the service in which it is engaged".

SEDCO Southeastern Drilling Company

Semisubmersible A column-stabilized, floating drilling platform with a buoyant substructure, part of which is beneath the surface of the water. Semisubmersibles are virtually self-contained, carrying supplies and personnel for drilling and completing wells in hundreds of feet of water.

Shear To cut the drill string with the shear rams in the blowout preventer in order to seal the bore completely and quickly against high well pressure, or to facilitate a rapid disconnect.

Single Side-band Radio (SSB) An internationally-adopted mode of radio communications. SSB refers to the suppression of one of the modulation side-bands or part of the carrier wave, resulting in a more efficient transmission while retaining quality.

Slip Joint The piston-like pipe joint at the top of a marine riser. The slip joint enables the rig to heave without damaging the riser.

SOLAS Safety of Life at Sea

Solenoid A solenoid is an electrical unit consisting of a coil of wire in the shape of a hollow cylinder and a moveable core. When energized by an electric current, the coil acts as a bar magnet, instantly drawing in the moveable core. Solenoids are used for electrically opening and closing quick-acting, plunger-type valves.

Solenoid Valve A valve operated electrically by use of an attached solenoid.

Sonar Survey An underwater survey using sound waves to identify the height and position of objects on the seabed.

SSB single side-band

Stability Report A daily report completed every morning by the ballast control operator listing fluid, ballast, anchor tensions, deckloads, weather conditions, and king gauge readings.

Steerage The minimum amount of forward movement that will enable a vessel to steer.

Stem The upright post or bar at the bow of a vessel.

SURPIC A graphic presentation of all ships known to be within a specified radius from a given point based on voluntary reporting by ships of their location to the U.S. Coast Guard at Governor's Island, New York.

Tank Level Gauge See King Gauge

Tasked A Search and Rescue resource is considered "tasked" when the appropriate Rescue Co-ordination Centre gives the order to participate in a search and rescue mission. Tasking can occur at the time of the alert or later, at the discretion of the RCC, depending on information available.

Tempered Glass Glass in which the breaking strength has been increased by a process of heating followed by rapid cooling in a liquid or air.

Thimble A round or heart shaped fitting around which an eye or loop may be spliced in hemp or wirerope. Its purpose is to protect the eye from the destructive effect of anything passing through it.

Time Line A graphic presentation of the unfolding of a search and rescue incident, depicting the first notice of the incident received by Search and Rescue through to the time when the operation ceases.

Transverse Running from port to starboard e.g., a transverse beam.

Travelling Block The moving portion of the hoisting equipment used to raise and lower the drill string.

Trim The inclination of a vessel to the bow or stern.

Tugger A small electrical, pneumatic or diesel powered winch used for routine hoisting operations. A number of these winches are located on a drilling unit's drill floor and in other areas to facilitate moving small loads. Also called a tugger winch.

Twenty-one Eighty-two See International Distress Frequency 2182 kHz.

Upwind The direction from which the wind is blowing.

USCG United States Coast Guard

Valve An automatic or manual device for controlling the passage of liquid or gas through pipe.

Valve Actuator A pneumatic or hydraulic piston which, when extended, opens an attached valve.

Vertical Centre of Gravity (VCG) If the total weight of a vessel and everything on board were concentrated in one single, imaginary point, this point would be termed the vessel's centre of gravity, and its location relative to the vessel's keel is identified as the vertical centre of gravity.

VFR visual flight rules

VHF very high frequency

VHF Radio A radio system using the very high frequency band between 30 and 300 megahertz.

Visual Flight Rules (VFR) The rules applying to aircraft operations during daylight hours under conditions of good visibility.

VON Call letters of the Canadian Coast Guard Radio Station, St. John's

Watertight Flat An internal, horizontal watertight divider or deck.

Weather Deck A vessel's exposed watertight main deck.

Well Control The practices and techniques used in balancing the pressures encountered in a well in order to prevent blowouts.

Wellhead The equipment installed on the seabed to maintain surface control of a well while giving access to the hole for the purpose of drilling and testing.

Wheelhouse A structure originally built on vessels over the steering wheel to protect the helmsman; now also used for navigational purposes, containing various control instruments.

Wirerope A rope made of metal wires twisted into strands and strands twisted into rope, often around a core of hemp or wire.

Work Vest A buoyant vest less cumbersome than a life preserver and worn by personnel working in an area of a vessel where there is a possibility of falling overboard.

Z Zulu or Greenwich Mean Time; international standard time based on the meridian of Greenwich, England. Reference to Zulu time in this report is expressed in terms of a 24-hour clock.

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This book is set in 10 point Times Roman
on 12 point body with Helvetica used
throughout the margins and appendices.
Cover and design by Dougal Dunbar.